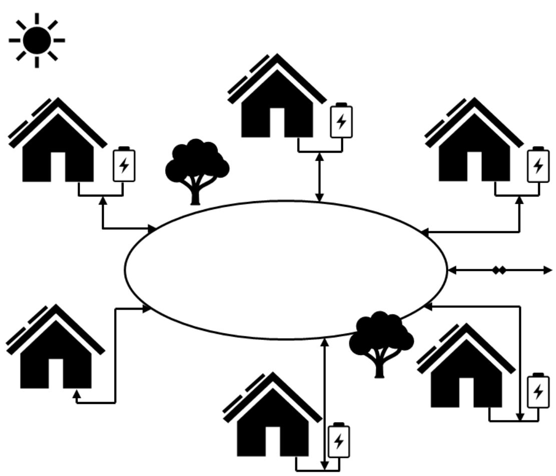
The willingness of Dutch citizens to participate in a prosumer community

A Stated Choice Experiment

L.F.J. (Luc) de Vet

Graduation thesis

MSc Construction Management and Engineering



Graduation Committee:

ir. A.W.J. (Aloys) Borgers (TU/e)

dr. G.Z. (Gamze) Dane (TU/e)

ir. L.A.J. (Wiet) Mazairac (TU/e)

ir. B. (Benny) Roelse (Sweco Nederland B.V.)

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Personal information

Student:	L.F.J. (Luc) de Vet
Student ID:	0955085
E-mail address:	lucdvet@gmail.com

Graduation committee

ir. A.W.J. (Aloys) Borgers	(Chairman TU/e)
dr. G.Z. (Gamze) Dane	(Graduation Supervisor TU/e)
ir. L.A.J. (Wiet) Mazairac	(Graduation Supervisor TU/e)
ir. B. (Benny) Roelse	(Graduation Supervisor Sweco Nederland B.V.)

Institute

University:	Eindhoven University of Technology
Department	Department of the Built Environment
Master Program:	Construction Management and Engineering

Graduation company

Company name:	Sweco Nederland B.V.

TABLE OF CONTENT

PREFACE

This thesis is the result of a research on prosumer communities as a potential for the sustainable transformation of the built environment. With this thesis, I complete the Masters of Science program Construction Management and Engineering (CME) at the Eindhoven University of Technology. The aim of the research was to investigate the willingness of Dutch citizens to participate in a prosumer community. Furthermore, the research focusses on the technical needs and financial feasibility to provide a complete overview of developing a prosumer community in the Netherlands. This research was conducted in collaboration with Sweco Nederland, a consultancy company that is specialized on designing and developing the societies and cities of the future.

Today, energy transition is becoming a more urgent issue in the Netherlands. The Dutch government is aware that a change is essential to achieve the set goals of reducing the greenhouse gases and increase the share of renewable energy sources. To achieve these goals, a sustainable transformation in the built environment is essential. Because this problem would be of major importance for the next decades, I think this graduation is an opportunity to enrich myself on this topic as a preparation for my professional career. Therefore, I was motivated to gain more insight in prosumer communities as a potential solution for the energy transition issue in the built environment.

During the previous five months, I have benefited from valuable guidance and helpful comments of my supervisors. First of all, I am especially grateful to the support and guidance of dr. Gamze Dane, who helped me from the start of my graduation project. I also want to thank ir. Aloys Borgers, for your detailed comments on my literature review and for helping me with the preparation and execution of my research approach and analysis. Thanks ir. Wiet Mazairac, for your insights and advices regarding the different technical topics of my research. In particular, I would like to thank ir. Benny Roelse for your technical and financial insights and for the opportunity to conduct my research at Sweco Nederland. I also want to thank my family and friends for their unconditional support during the difficult path of completing the MSc program.

Luc de Vet,
Eindhoven, August 2018

SUMMARY

Energy transition is becoming an urgent issue in the Netherlands. Therefore, the Dutch government aims to reduce greenhouse gas emissions to zero by 2050 and increase the share of renewable energy sources. In order to achieve this goal, the inadequate share of renewable energy sources should be expanded. When looking at the total energy distribution of the Netherlands, the residential built environment accounts for almost one-fourth of the primary energy demand. Therefore, the built environment can positively contribute to the aim of many cities to become energy neutral in 2050. Cities are expected to become more important in transitioning towards decentralized future energy systems, in which there are new opportunities for local energy concepts. A potential solution to increase the share of renewable energy sources in cities is the encouragement of citizens to become energy producers. Citizens need to change from being passive electricity consumers into active ones by becoming electricity producer-consumers: 'prosumers'. A prosumer can be defined as: "an individual or a household that will not only consume energy, but also produce energy by renewable energy resources and share the excess energy generated with the grid and/or with other consumers in a community". In a prosumer community, a large share of the electricity and heat is generated decentral, in which the demand and supply is matched by flexibility in the energy grid.

However, by looking at the scientific literature, the world's energy-related problems cannot only be solved by technological advances, but changes in human behavior are essential. The problem occurs by the little attention that is paid to energy behavior of individuals. This behavior of individuals needs to be shifted towards a more efficient and sustainable direction. Still little research is conducted on the decisive motivational factors that influence people's decision to participate in a local energy system. Therefore, the objective of this thesis is to gain insight in the decisive factors of Dutch citizens to participate in a prosumer community taking into consideration socio-demographic characteristics. Next to examining the behavioral aspects, this research also focusses on the individual and collective technical needs to realize a prosumer community and estimating the financial consequences.

As stated in the literature, prosumer communities can contribute to the total share of renewable energy by producing energy and sharing the excess of energy generated with the grid and/or with other consumers in a community. In this research, a new concept of a prosumer community is introduced as an addition to the current literature. In this concept, the energy efficient implementations are determined by their high energetic efficiency, general suitability and future potential. Furthermore, based on the ambition of the Dutch government to become more independent from the gas, the implementations in the introduced prosumer community are full-electric powered. The objective of a prosumer community is to maintain the energy generated as much as possible in the community. When there is an excess of energy, prosumers can sell their energy to the decentralized grid or main energy grid. This system can be combined with storage devices, in which it becomes possible to store energy surplus. This reduces the need for importing energy from the main energy grid. To estimate the financial consequences of a prosumer community, a financial analysis is conducted. However, from this analysis can be concluded that the introduced prosumer community is financially unprofitable. Moreover, the financial feasibility of a prosumer community is dependent on the gas price risings, the decrease in initial investment costs of a borehole thermal energy storage system and in-home batteries, and the encouragement of the Dutch government by subsidies to invest in high energetic efficiency implementations.

In this research, a stated choice experiment is executed to measure the preferences and choice behavior of citizens to participate in a prosumer community. In this research, two alternatives are presented to the respondents: own initiative and outsourcing of energy efficient implementations. Four attributes were selected from the literature to define the alternatives: financial consequences, community involvement, control of appliances and organizational participation. To each of these attributes, three levels are assigned. Next to the choice experiment, environmental statements were questioned to the respondents to gain insight in people's environmental conscious attitude. As a result of the data collection, 184 respondents are obtained who finalized the complete survey.

Based on the socio-demographic characteristics, the sample was not representative to the Dutch population, except for gender. The choice data was analyzed by estimating a multinomial logit model. Furthermore, a latent class model was estimated to discover classes in the sample. The objective of estimating the latent class model was to identify clusters of individuals who share the same choice behavior. It is important to find out whether these cluster share similar socio-demographic characteristics and environmental conscious attitude. According to the results of the latent class model, two classes were generated in which in class 1 can be identified as enthusiasts and class 2 can be identified as conservatives to participate in a prosumer community.

From the results of the multinomial logit model, multiple conclusions can be drawn. First, for the alternative own initiative and alternative outsourcing, it can be concluded that people prefer the financial consequences of implementing only solar panels instead of the financial consequences of implementing solar panels, borehole thermal energy storage (BTES) system and in-home battery. Secondly, for both alternatives, it can be concluded that there is a significant preference for own control of appliances instead of automatic control. Thirdly, for both alternatives, people do not prefer to be involved in organizational activities of a prosumer community. Finally, for the alternative outsourcing, it can be concluded that people are less prepared to participate in a prosumer community and outsource their investment when only 25 percent of the neighborhood is being involved. However, for both alternatives, there is a preference for 75% community involvement when participating in a prosumer community.

According to the estimated models, it can be concluded that there is support from Dutch citizens to generate their own energy and adopt a more energy-saving behavior. However, the extent of willingness to participate in a prosumer community is significantly dependent on the financial consequences of implementing energy efficient measures, a large share of the community that is involved, own control of appliances instead of automatically by a system and less involvement in organizational activities. Furthermore, it is of importance to focus on people based on their socio-demographic characteristics and environmental conscious attitude. Regarding the socio-demographic characteristics, people between 21 and 40 years that are higher educated, who own a dwelling and assign their self on average more as innovators, early adopters or early majority can be identified as enthusiastic to participate in a prosumer community. Moreover, based on the environmental statements, people that are willing to pay more for environmental friendly measures, prefer to be independent from large energy providers, willing to adopt a more environmental friendly lifestyle and prefer to be seen with solar panels on the dwelling are more willing to participate in a prosumer community. All in all, the extent of Dutch citizens to participate in a prosumer community is dependent on various factors; under favorable conditions, prosumer communities may be feasible. To encourage Dutch citizens for participating in a prosumer community, the first step would therefore be to take away the financial barrier. A built environment with a large share of prosumer communities can positively contribute to energy neutral cities by reducing the greenhouse gas emissions and increasing the share of renewable energy sources.

SAMENVATTING

In Nederland is energietransitie is een toenemend en urgent probleem. Om de energietransitie zoveel mogelijk te controleren streeft de Nederlandse overheid ernaar om de uitstoot van broeikasgassen tegen 2050 tot nul terug te brengen en het aandeel van hernieuwbare energiebronnen te vergroten. Om dit doel te bereiken, moet het ontoereikende aandeel van hernieuwbare energiebronnen worden uitgebreid. Als we naar de totale energieverdeling van Nederland kijken, is de gebouwde omgeving goed voor bijna een vierde van de primaire energievraag. Door dit gegeven kan de gebouwde omgeving positief bijdragen aan het doel van veel steden om in 2050 energieneutraal te worden. Van steden wordt verwacht dat ze nieuwe kansen bieden om lokale energieconcepten in praktijk te brengen in de overgang naar een gedecentraliseerd toekomstig energiesysteem. Een mogelijke oplossing om het aandeel van hernieuwbare energiebronnen in steden te vergroten, is de aanmoediging van burgers om energieproducent te worden. Burgers zullen dan veranderen van passieve elektriciteitsverbruikers in actieve elektriciteitsverbruikers door elektriciteitsproducent te worden: ‘prosumer’. Een ‘prosumer’ kan worden gedefinieerd als: " een persoon die, of een huishouden dat niet alleen energie verbruikt, maar ook energie produceert op basis van hernieuwbare energiebronnen en waarbij het overtollige energieverbruik dat wordt opgewekt, wordt gedeeld met het energienet en / of met andere consumenten / producenten in een community". In een prosumer community wordt een groot deel van de elektriciteit, warmte en koeling decentraal opgewekt, waarbij de vraag en het aanbod worden gecompenseerd door flexibiliteit in het energienetwerk.

In eerder wetenschappelijk onderzoek is aangetoond dat de wereldwijde energie gerelateerde problemen niet opgelost kunnen worden door enkel technologische vooruitgang, maar dat het veranderen van het energiegedrag van de mens hiervoor essentieel is. Dit energiegedrag van de mens zou verschoven moeten worden naar een efficiëntere en duurzame richting. Om deze verschuiving te bewerkstelligen, is het van belang inzicht te krijgen in de doorslaggevende factoren van Nederlandse burgers om deel te nemen aan een prosumer community. Naast het onderzoeken van de doorslaggevende gedragsaspecten, richt dit onderzoek zich ook op de individuele en collectieve duurzame energietechnieken om een prosumer community te realiseren en wat de financiële consequenties hiervan zijn.

Volgens de literatuur kunnen prosumer communties bijdragen aan het totale aandeel van hernieuwbare energie door energie te produceren en het overschot aan energie te delen met het energie net en / of met andere consumenten in een wijk. In dit onderzoek wordt een nieuw concept van een prosumer community geïntroduceerd als aanvulling op de huidige literatuur. In dit concept zijn de duurzame energietechnieken bepaald op basis van hoge energetische efficiëntie, algemene geschiktheid en toekomstpotentieel. Bovendien zijn, op basis van de ambitie van de Nederlandse overheid om meer onafhankelijk van het gas te worden, de duurzame energietechnieken volledig elektrisch aangedreven. Het doel van een prosumer community is om de gegenereerde energie zo veel mogelijk in de gemeenschap te houden. Wanneer er toch een overschot aan energie is, kunnen prosumers hun energie verkopen aan het gedecentraliseerde prosumer netwerk of het hoofdenergienet. Dit systeem kan worden gecombineerd met thuisbatterijen, waarin het mogelijk wordt om energieoverschotten op te slaan. Dit vermindert de noodzaak om energie uit het hoofdenergienet te importeren. Om de financiële consequenties van een prosumer community in te schatten, is een financiële analyse uitgevoerd. Uit deze financiële analyse is gebleken dat een prosumer community financieel niet rendabel is. De financiële haalbaarheid is namelijk afhankelijk van de stijging van de gasprijzen, de daling van de initiële investeringskosten en de aanmoediging van de Nederlandse overheid om te investeren in duurzame energietechnieken met een hoog energetisch rendement.

Om inzicht te krijgen in de doorslaggevende gedragsaspecten om deel te nemen aan een prosumer community, is er in dit onderzoek een keuze-experiment opgesteld en verspreid in de vorm van een enquête. In dit keuze experiment zijn twee alternatieven gepresenteerd aan de respondenten: eigen initiatief en uitbesteden van duurzame energietechnieken. Voor beide alternatieven zijn vier attributen uit de literatuur geselecteerd: financiële consequenties, deelname van de community, besturing van huishoudelijke apparaten en organisatorische betrokkenheid. Aan elk van deze attributen zijn drie niveaus toegewezen. Naast het keuze-experiment zijn er stellingen voorgelegd om inzicht te krijgen in de milieubewuste houding van de 184 respondenten.

Uit de data is gebleken dat behalve voor het kenmerk geslacht, de steekproef op basis van de sociaal-demografische kenmerken niet representatief is voor de Nederlandse bevolking. De data van dit keuze experiment is geanalyseerd door een multinomial logit model te schatten. Als aanvulling is er een latent class model analyse uitgevoerd om clusters van individuen te identificeren die hetzelfde keuzegedrag delen. Als resultaat zijn hier twee clusters uit voortgekomen waarbij cluster 1 kan worden geïdentificeerd als enthousiastelingen en cluster 2 kan worden geïdentificeerd als conservatieven om deel te nemen aan een prosumer community op basis van sociaal-demografische kenmerken en een milieubewuste houding.

Uit de resultaten van het multinomial logit methode kunnen meerdere conclusies worden getrokken. Ten eerste kan voor zowel het alternatief eigen initiatief als uitbesteden worden geconcludeerd dat mensen een voorkeur hebben voor de financiële consequenties van het installeren van alleen zonnepanelen in plaats van de financiële consequenties van een warmte-koude opslag en een thuisaccu. Daarnaast, kan voor beide alternatieven worden geconcludeerd dat er een duidelijke voorkeur bestaat voor het zelf bepalen wanneer huishoudelijke apparaten gebruikt worden, in plaats van een automatische besturing. Tevens zijn voor beide alternatieven mensen liever niet betrokken bij organisatorische activiteiten voor het opzetten en uitwerken van een prosumer community. Ten slotte kan voor het alternatief uitbesteding worden geconcludeerd dat mensen minder bereid zijn om deel te nemen aan een prosumer community wanneer slechts 25 procent van de community deelneemt. Voor beide alternatieven is er een voorkeur voor 75 procent deelname van de wijk bij deelname aan een prosumer community.

Volgens de geschatte modellen kan worden geconcludeerd dat er steun is van Nederlandse burgers om hun eigen energie te op te wekken en energiebesparend gedrag aan te nemen. De mate van bereidheid om deel te nemen aan een prosumer community is echter in grote mate afhankelijk van de financiële consequenties, een aanzienlijke deelname van de community, het zelf willen bepalen wanneer huishoudelijke apparaten gebruikt worden in plaats van automatisch door een systeem, en een passieve betrokkenheid bij de organisatorische activiteiten. Verder is het van belang om te focussen op de sociaal-demografische kenmerken en milieubewuste houding van individuen. Wat de sociaal-demografische kenmerken betreft, mensen tussen 21 en 40 jaar, die hoger opgeleid zijn, hun huis bezitten en zichzelf onderkennen als innovators, pioniers of voorlopers, worden aangemerkt als enthousiastelingen om deel te nemen aan een prosumer community. Bovendien, op basis van de stellingen, geven mensen die bereid zijn meer te betalen voor milieuvriendelijke maatregelen, de voorkeur onafhankelijk te zijn van grote energieleveranciers, bereid zijn om een milieuvriendelijkere levensstijl aan te nemen en liever gezien te worden met zonnepanelen op de woning meer bereid te zijn om deel te nemen aan een prosumer community. Al met al is de mate waarin Nederlandse burgers deelnemen aan een prosumer community afhankelijk van verschillende factoren; onder gunstige omstandigheden kan een prosumer community haalbaar zijn. Om Nederlandse burgers aan te moedigen om deel te nemen aan een prosumer community, is het advies om de financiële barrière weg te nemen. Een gebouwde omgeving met een groot aantal prosumer communities kan een positieve bijdrage leveren aan energie neutrale steden door de uitstoot van broeikasgassen te verminderen en het aandeel van hernieuwbare energiebronnen te vergroten.

ABSTRACT

Energy transition is becoming an urgent issue in the Netherlands. Cities are expected to become more important in transitioning towards decentralized future energy systems, in which there are new opportunities for local energy concepts. A potential solution to increase the share of renewable energy sources in cities is the encouragement of citizens to become energy producers: ‘prosumers’. In a prosumer community, energy is generated decentralized by renewable energy resources and the excess of energy is shared with the grid and/or with other prosumer/consumers in a community. However, the world’s energy-related problems cannot only be solved by technological advances, but changes in human behavior are essential. Therefore, the objective of this thesis is to gain insight in the decisive factors of Dutch citizens to participate in a prosumer community taking into consideration socio-demographic characteristics. In addition, a new concept of a prosumer community is introduced to the current literature in which energy efficient implementations are determined by their high energetic efficiency, general suitability and future potential. In this research, a stated choice experiment is applied in which data of 184 respondents is collected in the Netherlands. The estimated models show that the extent of willingness to participate in a prosumer community is significantly dependent on the financial consequences of implementing energy efficient measures, a large share of the community that is involved, own control of appliances instead of automatically by a system and less involvement in organizational activities. Furthermore, the results have proven that it is of importance to focus on people based on their socio-demographic characteristics and environmental conscious attitude. All in all, the extent of Dutch citizens to participate in a prosumer community is dependent on various factors; under favorable conditions, prosumer communities may be feasible. To encourage Dutch citizens for participating in a prosumer community, the first step would therefore be to take away the financial barrier. In conclusion, a built environment with a large share of prosumer communities can positively contribute to energy neutral cities by reducing the greenhouse gas emissions and increasing the share of renewable energy sources.

GLOSSARY

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This chapter introduces the topic of the graduation thesis by defining the research problem, formulating the research questions, presenting the research model, explaining the scientific and societal relevance, and finally providing a reading guide for the report.

1.1 CURRENT SITUATION

Global climate control has emerged as an important international issue. Therefore, 195 countries agreed on the Paris Climate Agreement in 2015 which contains two main targets of 30% CO_2 reduction in 2030 and 80-95% CO_2 reduction in 2050 (UNFCCC. Conference of the Parties (COP), 2015). As partner of the international community, the Netherlands is also required to achieve this goal. According to the Energy Agreement for Sustainable Growth (Sociaal-Economische Raad, 2013), the Dutch central government aims to reduce greenhouse gas emissions to zero by 2050. According to this agreement, the Dutch government ensures that the share of renewable energy sources will be 14% by 2020. In order to achieve this goal, the inadequate share of renewable energy sources should be expanded. This expansion is essential, because by comparing the current situation of the Netherlands with other European countries, it can be concluded that the Netherlands together with France are the farthest away from their national targets (Europadecentraal, 2017). By looking at this trend, it seems highly unlikely that they will achieve this goal. At the same time, the demand for energy in the world is continually rising. In combination with the expected population growth of 10 to 14 billion people by 2100, the global energy demand will almost double by 2050 (United Nations, 2004). This increase of demand is currently met by nonrenewable energy sources. However, society is facing the shrinking supply of scarce nonrenewable energy sources, which will not be able to meet the growing demand in the future. Alternative sources of renewable energy are required to meet the growing energy demand (Kesting & Bliek, 2013).

1.2 PROBLEM DEFINITIION

At present, the total share of renewable energy sources in the Netherlands is as little as 5.9 percent. According to the Central Bureau of Statistics, the share of renewable energy sources is increased in 2016 by 5 percent, but the energy usage has also increased by 4 percent in 2016 (CBS, 2017). Due to the increase in energy usage, the share of renewable energy sources is suppressed. The increase in energy usage can be attributed to larger demand in comfort of citizens (Udalov et al.,2017). When looking at the total energy distribution of the Netherlands, the residential built environment accounts for almost one-fourth of the primary energy demand (ING Economisch Bureau, 2013). Therefore, the built environment can positively contribute to the aim of many cities to become energy neutral in 2050. In this context, cities are expected to become more important in transitioning towards a more diverse, low-carbon, co-operative and decentralized future energy system (Koirala, 2017) According to Koirala (2017, p. 224), in this future energy system, "local energy systems can potentially contribute to the efficient overall energy production and distribution and also help meeting climate objectives by helping reversal of energy consumption and emissions trends". By looking at the current energy policy for the built environment, the aim is to realize in 2020 only nearly zero-energy buildings. Therefore, integration of local generation, energy efficiency and demand side management are becoming increasingly important in the local energy landscape. In this local energy landscape, centralized coordinated power systems are transformed towards bottom-up decentralized low-carbon systems (Koirala, 2017). These developments contribute to new opportunities for local energy concepts to provide smarter, flexible and integrated systems. Therefore, in this thesis, the focus is on mainly on residential consumers and the encouragement of collective bottom-up energy initiatives.

A potential solution to increase the share of renewable energy sources in cities is the encouragement of citizens to become energy producers. Citizens need to change from being passive electricity consumers into active ones by becoming electricity producer-consumers: ‘prosumers’ (Pal, Chelmis, Frincu, & Prasanna, 2016). According to Zafar et al. (2017, p. 1) and many other researchers (Kesting et al., 2013; Prakashet al., 2015; Rathnayaka et al., 2014), the term of prosumer can be defined as: “an individual or a household that will not only consume energy, but also produce energy by renewable energy resources and share the excess energy generated with the grid and/or with other consumers in a community”. In a prosumer community, a large share of the electricity and heat is generated decentral, in which the demand and supply is matched by flexibility in the energy grid. The decentralized energy generated arises from the integration of renewable energy into buildings, which involves several technologies and infrastructures. These energy efficient implementations includes solar heating and cooling, low-energy or “passive” buildings, district heating and cooling, “building-integrated” solar PV, and thermal energy storage (Ren21, 2013). According to the renewables global futures report (2013), the decentralized renewable energy generated emerges in the future as a complex combination of on-site, mini-grid, and energy storage at all levels.

However, on a global scale, researchers and policy makers are looking extensively for new cost-effective solutions and new technology to increase household efficiency and conservation (Frederiks et al., 2015). However, according to Frederiks et al. (2015), these energy efficient implementations are required to reduce the extensive emissions of greenhouse gases, yet their net benefits have been overestimated. The world’s energy-related problems cannot only be solved by technological advances, but changes in human behavior are essential. However, the problem occurs by the little attention that is paid to energy behavior of individuals. This behavior of individuals needs to be shifted towards more efficient and sustainable direction. In addition, Schweizer-Reis (2008) underlined that energy efficient technologies are developed to solve the problem, but finally the end-users “decide” whether they adopt an energy-saving behavior and decrease their energy consumption.

In the context of this thesis, local prosumer communities can be well-placed to identify local energy needs, establish and support of initiatives and bring people together to achieve a common goal (Koirala, 2017). However, still little research is conducted on the decisive motivational factors that influence people’s decision to participate in a local energy system. Therefore, the objective of this thesis is to gain insight in the decisive factors of Dutch citizens to participate in a prosumer community. As a result, bottom-up initiatives can be encouraged with an area-based approach based on socio-demographic characteristics.

1.3 RESEARCH QUESTIONS

Prosumer communities provide new opportunities for decentralized energy generation and new roles for citizens and communities. These local energy initiatives are essential for cities to become energy neutral and positively contribute to the renewable energy share of the Netherlands. This is in line with urgency for the Dutch government to achieve their renewable energy targets that are suppressed by the growing energy demand. Besides all technological opportunities and elaborations, the behavioral aspects are important to consider. As discussed, little research is conducted on the psychological aspects in combination with the socio-demographic characteristics. These factors might have a major influence on people's decision to participate in a local energy system as a prosumer community. For this thesis research, the following main question is examined:

To what extent are Dutch citizens willing to participate in a prosumer community?

The main question will be answered by the following sub-questions in Table 1:

Table 1 Sub questions

	Question:	**Methodology:**
SQ1.	What are the technological needs to realize a prosumer community at the individual and community level?	Literature review, interviews with experts of Sweco
SQ2.	To what extent can a prosumer community be financially optimized?	Literature review, interviews with experts of Sweco
SQ3.	What are the decisive motivational factors for people to participate in a prosumer community?	Stated choice experiment, literature review
SQ4.	To what extent is the willingness of Dutch citizens to participate in a prosumer community influenced by decisive motivational factors?	Stated choice experiment

1.4 RESEARCH DESIGN

In Figure 1, the research model of the graduation project is presented. As can be seen, the model is divided in three sub-divisions starting with the literature review. For a sufficient financial analysis, first research on the technical level is considered to gain insight in which energy efficient implementations are necessary at the individual and community level. For the research on both technical and financial aspects, the expertise of Sweco Nederland is considered. To finalize the literature review, research is elaborated on people's energy curtailment and investment behavior. When the literature review is finished, the researched subjects are considered in designing the stated choice experiment. For the elaboration of the stated choice experiment, an online survey is developed and distributed. To analyze these results, a Multinomial Logit Model and Latent Class Model are estimated. Finally, when the complete research is conducted, scientific and societal conclusion are drawn to finalize the graduation project.

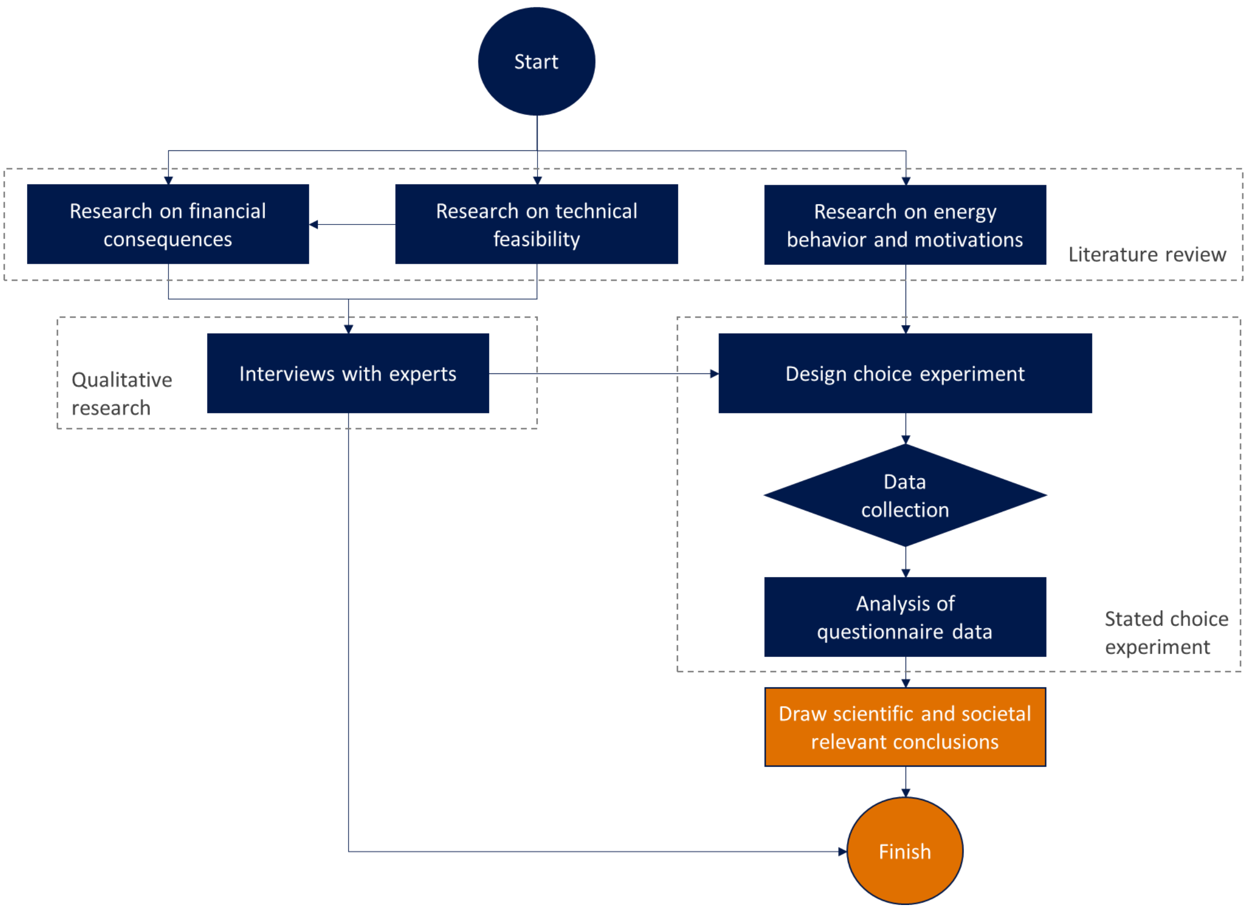

Figure 1 Research model graduation project

1.5 SOCIETAL AND SCIENTIFIC RELEVANCE

1.5.1 Societal relevance

Today, the Dutch government is sharpening their policy to increase the share of renewable energy in the Netherlands. In their policy, goals are established to obtain energy neutral cities in 2050 and to become less dependent on the national gas resources. Because the built environment accounts for almost one-third of the primary energy demand (RVO, 2015), a reduction is essential. Therefore, the government has already approved on restrictions on new developments from 2020 to meet the Nearly Energy Neutral Buildings (also called in Dutch: Bijna Energy Neutraal Gebouw BENG) requirements. These requirements can only be met when energy efficient implementations are applied in buildings. However, new residential development is a fraction of the total built environment and will not rapidly contribute towards energy neutral cities. To encourage this process, changes in the existing residential built environment are essential. To realize more energy efficient implementations in existing neighborhoods, citizens play an important role. Especially, when citizens not only implement for example solar panels by their own, but work together in a collective with their neighborhood. As can be imagined, people might be more willing to invest in energy efficient implementations when other neighbors are also participating. However, since today, no research is conducted on measuring the willingness of citizens to participate in a prosumer community in the context of the Dutch situation. Therefore, this research will give insight in people's decisive motivations to participate in a prosumer community is obtained.

1.5.2 Scientific relevance

As discussed, the world's energy-related problems cannot only be solved by technological advances, but changes in human behavior are essential as well. However, relative little attention has been paid to energy behavior of individuals in the literature. This behavior of individuals needs to be shifted towards more efficient and sustainable direction (Frederiks et al., 2015). In the current literature, most research is conducted on energy-saving behavior and investment behavior in energy efficient implementations (Han et al, 2013; Yue et al., 2013). Additionally, research focuses more on individual motivations and considerations and less on how people can be encouraged to collectively set up an initiative as a prosumer community. A prosumer community is considered in the current literature as a solution for increasing the share of renewable energy and to achieve energy neutral cities (Kesting et al, 2013; Prakash et al., 2015; Rathnayaka et al., 2014; Zafar et al., 2017). Furthermore, the results of this thesis can also contribute to the research on financial optimization models, to examine how a prosumer community can be financially optimized. This is of importance because investing in energy efficient implementations is dependent on people's main motivation: financial consequences (Das et al., 2018; Frederiks et al., 2015; Wang et al., 2011). In the literature, financial benefits are assigned as the most important decisive motivation of people to invest in energy efficient implementations. However, less research is conducted on how people act when there is an initiative in their neighborhood and which organizational role they prefer by participating. Therefore, future research in this field should focus more on behavioral aspects by encouraging energy efficient implementations. Therefore, the objective of this thesis is to gain insight in the decisive motivations of Dutch citizens and to encourage bottom-up initiatives with an area-based approach based on socio-demographic characteristics.

1.6 THESIS OUTLINE

This thesis consist of seven chapters in which different topics are discussed and elaborated. The first chapter includes the problem statement and research objective that results in the research question. This chapter further discusses the scientific and societal relevance is of this research. Chapter 2 presents the scientific and relevant topics to define a prosumer community based on the current literature. Furthermore, the energy efficient implementations that are necessary at the collective and individual level are described and a new concept of a prosumer community is introduced. This chapter also describes the current policy of the Netherlands towards the encouragement of energy efficient implementations. When the technological needs are determined, the financial consequences need to be calculated. Therefore, chapter 3 discusses the price expectations for the future, investment strategies and provide a financial model to determine the financial consequences for three scenarios. To gain insight in the energy behavior of people, chapter 4 reviewed the current literature on decisive motivational factors and the influence of socio-demographic characteristics on the curtailment and investment behavior of people.

Furthermore, in chapter 5 the research approach is explained for executing a stated choice experiment. The aim of this research approach is to provide information on why the choice experiment is selected and how it is set-up according to the methodology of Hensher et al. (2005). Based on the output of the questionnaire that is developed for the stated choice experiment, different statistical analyzes are conducted in chapter 6. In this chapter, results are analyzed by estimating a Multinomial Logit and Latent Class model to the stated choice behavior of respondents. Finally, the scientific and societal relevant conclusions are drawn in chapter 7. This chapter also discusses recommendations, based on the limitations of this project.

2 THEORETICAL FRAMEWORK

This chapter presents the relevant and scientific subjects on prosumer communities based on the current literature. The chapter provides multiple definitions of developments and solutions that are proposed regarding to the concept of a prosumer community. Furthermore, the ambition towards energy neutral buildings of the Dutch government is described. Finally, the individual and collective energy efficient implementations are determined by their high energetic efficiency, general suitability and their future potential that are essential in realizing a prosumer community. By determining these implementations, a new concept of a prosumer community can be added to the existing literature.

2.1 A PROSUMER COMMUNITY: THE DEFINITION

In the last decades, the major paradigm shift in the energy grid concept is the change of electricity consumers from being passive consumers to become active ones by becoming electricity producer-consumers: 'prosumers' (Pal et al., 2016). According to Zafar et al. (2017, p. 1) and many other researchers (Kesting et al., 2013; Prakashet al., 2015; Rathnayaka et al., 2014), the term of prosumer can be defined as: "an individual or a household that will not only consume energy, but also produce energy by renewable energy resources and share the excess of energy generated with the grid and/or with other consumers in a community". A prosumer produces, purchases and consumes energy that is derived from renewable sources such as wind, solar or residual heat from biomass. By generating sustainable energy from renewable energy sources, prosumers can interact with the energy market because they want to sell / share their surplus with other consumers in the community, but can also be completely independent and self-serving by local storage devices. The concept of a prosumer is summarized in Figure 2.

Today, most prosumers are individually connected to the utility grid. A major disadvantage is the exclusion of individual prosumers to the wholesale energy market of ENDEX, APX and IMBAL that is caused by their perceived inefficiency and unreliability. The exclusion can be attributed to the unpredictable supply of renewable energy sources by uncertain weather conditions to compete with non-renewable power generators. Secondly, to speed up the process of realizing more energy neutral cities and achieving the renewable energy goals by the Dutch government, more people need to be encouraged to become a prosumer. Rathanayaka et al. (2014) propose a prosumer community group (PCG) as a possible solution. The term in their research is defined as "a network of prosumers, having relatively similar energy sharing behaviors, who endeavor to pursue a mutual goal and jointly compete in the energy market". Because of the accumulated quantity of prosumers, the share of the renewable energy generation increases and people in the community can manage their own demand and supply. In addition, the negotiation power of prosumers results in the elimination of the exclusion from the energy market.

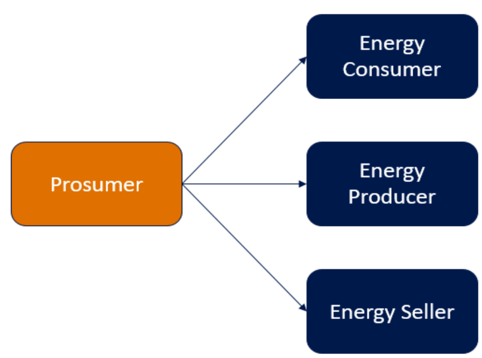

Figure 2 Prosumer concept

2.2 SMART ENERGY GRID

2.2.1 Smart grid for prosumers

To realize a reliable bi-directional flow in the energy grid for prosumers, a different approach in the energy grid is essential. Originally, the energy in the electricity grid flows from the central power plant to the consumers, in which reliability is ensured by preserving surplus capacity. However, this one directional flow within the grid is an incompetent system that a foremost emitter of greenhouse gases, consumer of fossil fuels and not well suited for renewable energy sources (Ali, 2013). In addition, the power grid is facing new challenges by sustaining the higher demands and reliability concerns. In recent years, there has been a major paradigm shift in the way electricity is generated, transmitted and consumed by the use of more renewable energy sources. By facing all challenges and future developments, the grid needed to be transformed into a more efficient, reliable and communication-rich system (Ali, 2013). To realize a bi-directional energy flow between the energy users and the utility grid, the concept of smart grid has been proposed (Rathnayaka et al., 2014). According to many researchers (Ali, 2013; Rathnayaka, Potdar et al., 2014; Zafar et al., 2017), the concept of Smart Grid is a potential system to address all the above challenges. Zafar et al. (2017) defines a smart grid as "an advanced power system with integrated communication infrastructure to enable bi-directional flow of energy and information". The bi-directional flow ensures that electricity and information can be exchanged between the utility and the customer. Furthermore, the system can be managed at both the demand and supply side. The smart grid system can also monitor energy behavior and actions of all users connected in order to deliver sustainable balance in supply and demand (Rathnayaka et al., 2014). According to Ali (2013) in his book Smart Grids: Opportunities, Developments, and Trends, smart grid is an opportunity to use new information and communication technologies (ICTs) which offers a greater monitoring and control. This concept increases the electricity efficiency and provides more insight in the energy usage, by increasing the awareness for consumers about their usage (Rodríguez-Molina et al., 2014). Table 2 shows the significant changes that are expected by implementing smart grid compared to the traditional grid.

Table 2 Smart grid compared (Rodríguez-Molina et al., 2014)

Environment	Without Smart Grid	With Smart Grid
Data	Offline, scarce data One-way stream	Online, abundant data (big data) Two-way interchange
Business models	Producers and consumers Static business models	Prosumers Dynamic business models
Energy	Focus on fossil-based Non-renewable energies Centralized energy production	Focus on renewable energies Distributed energy production
Information and communication technologies	Weak preventive mechanisms Little use of information and communication technologies Infrastructure with scarce intelligence	Strong preventive mechanisms Widespread use of information and communication technologies Information inference and decision making features
Agents	Reduced amount of participating agents	Potentially huge amount of participating agents

2.2.2 Virtual power plants or micro-grids?

As described, the power network is based on radial topology in which one generator is attached to many consumers by large high-voltage and long-distance transmission networks (Platt et al., 2012). This traditional network is not appropriate for prosumer community groups, because of the one-directional flow. In literature two energy sharing processes in electrical infrastructure solutions are proposed to connect prosumer community groups by smart grids: Virtual Power Plants or Micro-Grids. In literature a Virtual Power Plant is identified as a group of distributed energy recourses with an aggregated capacity. The major advantage of a VPP in contrast to an individual prosumer is that VPPs can communicate with the balance responsible party and even negotiate with different distributed energy sources. There are two types of VPP management infrastructures, namely: centralized architecture and decentralized architecture. First, centralized architecture in which grid-connected prosumers are controlled by a centralized controller. This centralized controller is responsible for capturing and analyzing power flow information and compose decisions accordingly to the control of the prosumer. In contrast, decentralized architecture is independent from a central controller and empowers participating prosumers to autonomously perform certain communications and decision making tasks (Rathnayaka, 2014). The second energy sharing electrical infrastructure of prosumer community groups is a micro-grid. A micro-grid can be identified as a localized connection of distributed energy resources by a committed infrastructure. Despite the similar concept of the micro-grid and VPP, there is a difference. Micro-grids are more concerned with locality because of their smaller size, while VPPs can vary from small to large sizes and are more focused on large scale energy sharing. However, in the concept of micro-grids compared to VPPs, transaction costs are lower which can be contributed to the lesser number of intermediary parties. Furthermore, a major shortcoming in both concepts of prosumer community groups is in the dedicated technical infrastructure. This is caused by the fixed architecture that results in inflexibility by removing or adding a prosumer to the grid (Rathnayaka et al., 2014).

2.2.3 Controlling demand and supply of energy

By implementing a smart grid bi-directional flow of information, prosumers can gain detailed insight into their energy production and consumption by information communication technologies (ICT). These ICT solutions are called ‘smart metering infrastructure’. According to Leiva et al. (2016) smart metering infrastructure (SMI) can be defined as “an electronic system that is capable of measuring energy consumption while providing more information than a conventional meter and that can transmit and receive data using a form of electronic communication”. According to Leiva et al. smart metering infrastructure allows gaining information of energy consumption in an objective and transparent manner. By gaining detailed information, people can evaluate their energy consumption and production profiles as prosumers. The monitored data can for example be visualized by in-home wall displays, smart phone apps or computers. By actively using the visualized data, end-users can easily access their consumption and production data which lead to an average energy saving of 3% by changes in people’s energy behavior (Vringer & Dassen, 2016). According to Kesting and Bliek (Kesting & Bliek, 2013), the detailed energy information can also be shared with other users in the neighborhood. By comparing people’s energy consumption with the average of, for example, the whole prosumer community, consumers can be enticed to reduce their own energy consumption.

Next to the energy-saving potential, there is a large potential for smart metering infrastructure on the technical aspect. A smart meter replaces the traditional gas and electricity meters and also registers a possible energy supply. The network operator can automatically and remotely read the meter data using ICT and can better control demand and supply (Vringer & Dassen, 2016). When looking at the household level of Dutch households, almost 3 million smart meters are already installed, which is almost 40% of the total households. This development can be contributed to the decision of the Dutch government to install a smart meter in all 7.8 million households. In 2020 all households should have a smart meter, which was intended to lead to an average saving of 3.5%. However, in November 2016 the planning agency for the living environment concluded that the energy saving of installing smart meters is hardly 1%. Still, the Dutch government continues with the implementation and considers the in-home displays as a more potential solution. According to the research of Vringer and Dassen (2016), the progress of in-home displays should be expanded, because of their major potential savings. The savings when all Dutch households would install an in-home display, is estimated to a saving of 1.500.000.000 kWh per year. In addition, Vringer and Dassen (2016) examined that in-home displays can level the unpredictability of solar and wind energy.

When prosumers reduce their energy consumption by Smart Metering Infrastruture solutions, there might arise an energy surplus. This energy surplus can be distributed to the energy grid, in which prosumers can sell their energy to people who prefer sustainable energy. The mechanism of selling the surplus is arranged by demand side management. According to (Razzaq et al., 2016, p. 2), demand side management (DSM) is "a developed tool for load shifting to off-peak hours in order to fulfill the energy demand as well as minimize the energy cost, which results in a balanced power production curve". Ali (2013) states that with the expected increase in PV panels, the supply power may fluctuate by changes in the weather characteristics. This imbalance between demand and supply leads to fluctuations in the system frequency and may negatively affect user appliances and power outage. This issue can be solved by the second major element of DSM, which are demand-supply control technologies and storage devices. Because the energy from peak hours is stored, the need for energy from the main energy grid is reduced. DSM can be implemented by introducing price dependent time slots and reduced energy consumption during peak hours (Razzaq et al., 2016). According to Behrangrad (2015) the activities of DSM can be classified into "Energy Efficiency (EE)" and "Demand Response (DR)". Energy efficiency reduces the energy required for the provision of services or products and Demand Response changes people's energy consumption patterns in response to changes in energy prices over time, or by incentive payments designed to persuade people lower electricity use at times of high wholesale market prices (Behrangrad, 2015). As an example of DR, a consumer can reduce their non-critical energy loads when they know that the electricity price will be considerable higher. This system increases the financial attractiveness for people to become prosumer, especially when the nonrenewable energy prices will rise.

2.3 AMBITION DUTCH GOVERNMENT

Next to the current developments in technology that are explained in the literature, the Dutch government has also ambitions regarding energy transition. These ambitions result in new proposed regulations for the next coming decades. The Dutch government aims to decrease the primary fossil energy usage and to encourage the implementation of the energy efficient installations. In their policy, dwellings built from 2020 are obliged to meet the nearly Zero Energy Buildings (nZEB) requirements, also known in Dutch as “Bijna Energie Neutraal Gebouw (BENG)”. In 2015, an important intermediate step is established in which the energy performance coefficient (EPC) for homes is adjusted from 0.6 to 0.4. This objective applies to building-related energy use, including: heating, domestic hot water, ventilation, cooling and lighting (RVO, 2014). For all new buildings after 1 January 2020, the permit applications must comply with the requirements for almost zero-energy buildings (BENG). In BENG, the energy performance of a building is measured by three indicators: the energy needs of a building, the primary fossil energy use and the share of renewable energy. Individual requirements are determined for these indicators in which they will replace the requirements of the current EPC. In Table 3 the requirements for the BENG indicators are defined. The requirements of BENG are the result of the Energy Agreement for sustainable growth and the European directive EPBD and are only focused on building-related energy flows (Bouwens, 2017).

Besides the EPC and the BENG at the building level, there is an energy performance coefficient for districts: NVN 7125 - EMG. The energy performance coefficient for energy efficient implementations at the district level (EMG) is since 2012 the standard for collective energy efficient solutions. Dwellings in a district can achieve a lower EPC when there are energy efficient implementations at the district level. However, to prevent that building with a collective energy supply incorrectly meet the EPC-requirements, for example in the case of insufficient insulation, the EPC of a building may maximally increase by one third.

Table 3 Requirements per BENG indicator

	Indicator	Definition	Requirements	Achieve requirements by:
BENG 1	**Energy needs**	Need for energy for heating and cooling. Note: due to the risk of overheating, becomes a fictitious surcharge calculated for 'summer comfort'.	Up to 25 kWh / m2 per year thermal	Urban design, orientation, compact design, shell insulation, airtightness, summer night ventilation, ventilation system, sun protection
BENG 2	**Primary fossil energy use**	The amount of fossil fuel used for heating, cooling, hot water and installations.	Up to 25 kWh/m2 per year primary fossil	Efficient installations, heat output at low temperature, hot water with short pipes and heat recovery, application renewable energy (also BENG 3).
BENG 3	**Share of renewable energy**	The amount of renewable energy divided by the total primary energy use (fossil + renewable).	At least 50%	Application of PV, solar water heater, soil energy, ambient heat, biomass, external heat supply (if renewable).

The second important ambition of the Dutch government is the abolition of the obligation to connect to the gas network for new residential dwellings. Recently, the house of representatives has passed the law progress energy transition (also called in Dutch: Wet Voortgang Energietransitie (VET)), in which the legal obligation for network operators for the connection of gas (obligation to connect) is abolished with this law. When the Dutch Senate also decides to pass the law proposal, there will be no new residential dwellings connected to the gas network. In the VET, households have the right to an alternative energy supply, such as connection to a heating network or a heavier electricity grid. The abolition is of importance because today, seven million households, companies and institutions are connected to the approximately 130,000 kilometers of gas pipeline that distributes Groningen gas over the Netherlands. For the coming years, the construction of more than 40,000 new homes is planned each year. Last year Nature and Environment calculated that if 230,000 homes are built gas-free in the next five years, this amounts to an annual saving of 230 million cubic meters of natural gas (Graaf, 2018). For this research, it is assumed that prosumer communities have no connection to the gas network. Therefore, all gas powered systems, for example combined heat and power (CHP) systems, are not elaborated.

2.4 ELABORATION OF A PROSUMER COMMUNITY

In the previous sections, the theoretical background on prosumer communities and the ambition of the Dutch government is explained. In so far, SQ1: "What are the technological needs to realize a prosumer community at the individual and community level?" need to be answered. Therefore, the objective of this section is to present how a prosumer community can be realized in the Netherlands based on the Dutch ambitions and regulations. Furthermore, this section focusses on energy efficient implementations that are selected on their high energetic efficiency and their potential regarding future developments as an addition to examples in the current literature. Finally, the aim of this section is to increase the understandability of prosumer community into a practical case.

2.4.1 Energy efficient implementations district and individual level

When the architectural and urban design of a building or district cannot be designed more efficient, renewable energy sources can be implemented. In this section, energy efficient implementations are determined that can be applied to new dwellings. The objective is to gain insight in the most energy efficient implementations at the individual and community level to minimize the heating, cooling and electricity demand of dwellings. The implementations are discussed on their high energetic efficiency, their general suitability and future expectations to be implemented in a prosumer community. Furthermore, the aim is that a prosumer community is full-electric powered, which means that there is no gas demand. This section starts with overcoming the heating and cooling demand in which an underground thermal energy storage is proposed. In comparison with other energy efficient implementations, this system have a high energetic efficiency for the heating and cooling demand. The energetic efficiency is a ratio between the outgoing useful energy and the energy that goes into it, in which 100% thermal efficiency is the base. When for example calculating the heating demand, the underground thermal energy storage system has an energetic efficiency of 450%. This means that per kWh that goes into it, 4.5 kWh can be obtained. In contrast, by calculating the space heating demand for a gas boiler, the thermal efficiency is 90%. This means that per m3 gas that goes into it, 0.9 m3 gas can be obtained, which indicates that more m3 gas is necessary to meet the heating demand of the dwelling. To power this system by electricity and meet the energy consumption demand of households, solar panels are proposed. Finally, in-home batteries are recommended for storing the residual electricity during the daily fluctuations of PV panels and selling the residual electricity to other prosumers in the grid. These implementations are discussed in this section. However, it is assumed that the decentralized generation of energy in prosumer community cannot be 100 percent self-providing. Therefore, it is assumed that at least 20 percent of the energy is imported from the energy grid.

Underground Thermal Energy Storage

To overcome the heat demand of a prosumer community, an underground thermal energy storage (UTES) system can be implemented. UTES is a high energetic efficiency system that uses natural underground sites for storing thermal energy for seasonal purposes. The ground and groundwater are suitable for extracting heat during the winter and cold during the summer. The ground below 10-15 meter is not influenced and equals to the annual mean air temperature (K. S. Lee, 2013). According to Kun Sang (2013), the difference between the outside air and the ground can be applied as preheating in winter and precooling in summer by using a ground heat exchanger. In winter, this heat exchanger is of high efficiency and pumps the heat into the conditioned space. In summer, the process is reversed in which the heat pump extract heat from the conditioned space and pumps it by a heat exchanger into the relative cool ground. Because this system has a substantial impact when implemented in existing dwellings, it is assumed that this system is only realized in new built dwellings. Furthermore, this system is in line with the assumption of this research by having a higher energetic performance and efficiency. Especially, because the UTES system is the only suitable system that can overcome the cooling demand more efficient by comparing it to the alternatives, for example an air-water heat pump. The UTES includes the following two systems: Aquifer Thermal Energy Storage (ATES) for collective usage and Borehole Thermal Energy Storage (BTES) for individual usage.

Based on the energy performance, a subsidy for a heat pump can be claimed between 1.000 and 2.500 euro. This subsidy is provided by the investment subsidy for sustainable energy (ISDE) financed by the Dutch government. However, for both Aquifer Thermal Energy Storage (ATES) as Borehole Thermal Energy Storage (BTES) no subsidy can be claimed. The two systems are explained below.

Aquifer Thermal Energy Storage (ATES)

Aquifer Thermal Energy Storage (ATES) is an open-loop collective system that extract groundwater from aquifers using a water well for energy storage (Figure 3). In this system, the heated and cooled groundwater is stored in the ground to enhance heating and cooling mode cycles (K. S. Lee, 2013). The ATES system works as follows: the natural cold of the winter that is stored in aquifers, can be used in summer for cooling purposes. The system requires a warm well and a cold well to store the thermal energy seasonally. When there is a cooling demand, cold water is extracted from the cold well and is then returned to the warm well at a higher temperature. When there is a heating demand, water is extracted from the warm well and is elevated in temperature by a heat pump. After the heating load is provided, water returns to the lower temperature cold well (Nordell et al., 2015). The ATES system can be designed for individual installation at large building, for example apartments and large buildings and collective installation of neighborhoods. However, the municipality or an individual company need to provide land to exploit the aquifers and being the owner. In addition, the ATES system is barely realized individually in dwellings because of high initial investment and maintenance costs. Therefore, as a rule of thumb, the electric power for an ATES system is at least 70 kW. The ATES system is mainly used in neighborhoods with at least 120 dwellings. For a collective installation, groundwater from a collective aquifer is supplied to multiple dwellings in which central heat is generated and distributed via one network to the users.

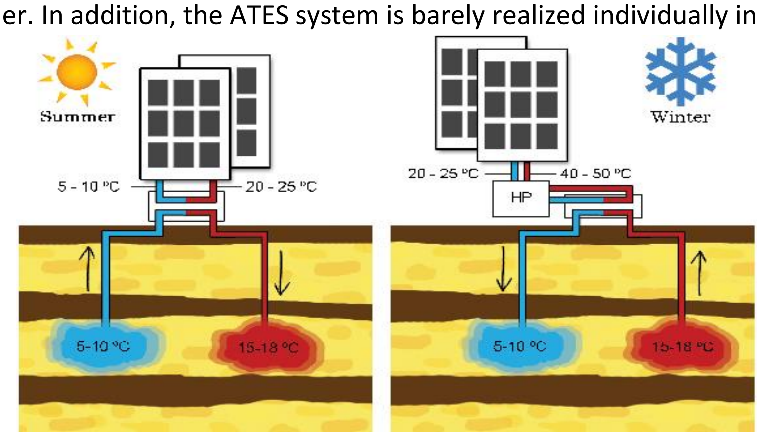

Figure 3 Aquifer thermal energy storage (ATES) system

Borehole Thermal Energy Storage (BTES)

The second system that can be considered when it is not possible to exploit an aquifer, is a Borehole Thermal Energy Storage (BTES) system (Figure 4). In this system, vertical ground heat exchangers are inserted into the underground, in which thermal energy is transferred toward the ground (K. S. Lee, 2013). In a closed loop, a mixture of water and antifreeze is pumped through the borehole heat exchangers. The system provides a seasonal process to meet the heating and cooling demand. In summer, the cold water is extracted from the soil and distributed through a heat pump, which meets the cooling demand in the building (Mangold & Deschaintre, 2015). The cold water from the aquifer is warmed by the heat of the dwelling and is subsequently drained through the same closed-loop. The residual summer heat is distributed by a heat pump and is drained to the soil, which is warmed-up. In the winter, the heat from the soil is extracted, heated by a heat pump and is released to the dwelling. This process is the same when there is a demand for warm tap water, for example showering. This warm water is saved in a boiler barrel for direct usage. The residual winter cold is distributed through the same closed-loop and is drained to the soil. The soil is therefore cooled and will be used in the summer for the cooling of the dwelling. The BTES closed-loop system is more suitable for individual installation at dwellings, in which the energy power is below 70 kW. Sharing of a closed-loop with neighbors is not possible because of property-ownership implications of the land. Furthermore, due to a larger energy demand, the source is more rapidly depreciated and it is unknown which dwelling demanded the most energy. In comparison to an ATES system, the initial cost of a BTES system are lower and the closed-loop needs no maintenance.

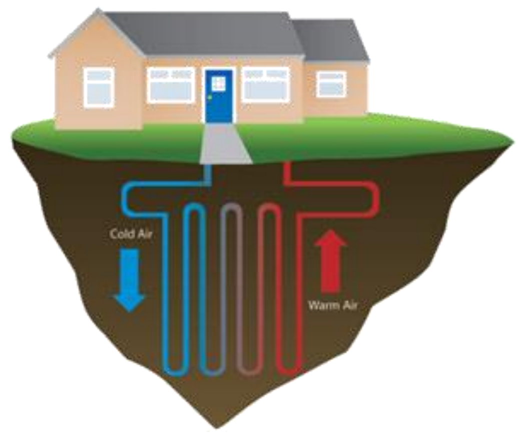

Figure 4 Borehole thermal energy storage (BTES) system

Photovoltaic panels

To provide electricity for the heat pump and the daily energy consumption of households, photovoltaic (PV) panels are a potential solution for the generation of energy. The major benefit of PV panels is that the sunlight can be directly converted into electricity. With a radiation efficiency of 22%, PV panels are highly suitable for households (Sharma et al., 2015). At present, 600.000 dwellings have solar panels installed, which accounts for 5 percent of the nine million dwellings in the Netherlands. This number is limited because it contributes for slightly 2 percent of the total energy demand of the Netherlands. Solar panels can both be applied at the individual and district level. The most common use of PV panels is at the individual household level, in which people install panels on their roof. For consumers, solar panels are financially attractive because of their short payback period of 6 to 8 years and a tax rebate can be claimed on the investment. According to the RVO (2018), if a private individual purchases solar panels, the VAT from the Tax and Customs Administration on purchase and installation (21 percent) can be reclaimed. Despite all the advantages, this energy has a few limitations. First, PV panels are dependent on sunlight and will therefore daily fluctuate in intensity and radiant energy. The intensity and radiation are also influenced by the season or by the position of the dwelling (Sharma et al., 2015). Secondly, the investment in PV panels is reasonable high despite the short payback period according to the 'salderen' policy. By this regulation, the generated energy by solar panels is subtracted to the amount of energy a household uses that year at the same rate. For example: if a household consumes 3,500 kWh and their solar panels generated 1.250 kWh, the annual account is for 2,250 (3,500 – 1,250). However, this regulation seems to be abolished by the government in the near future and changed to a feed-in fee per generated kWh. Because the generation and use of energy differs over time (see Figure 5), a potential solution is the storage of energy to re-use it at a different time.

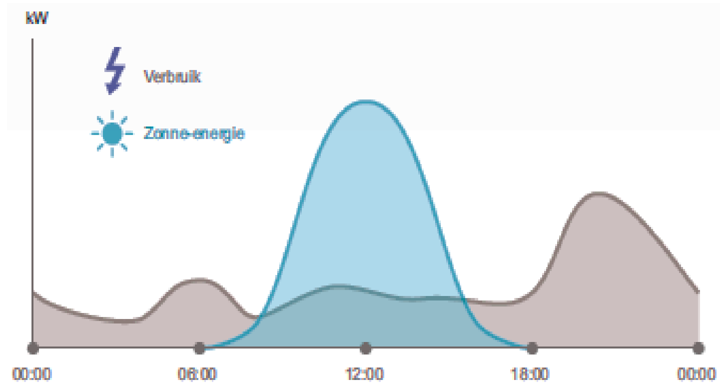

Figure 5 Energy balance at sunny day

In-home batteries

To store the residual electricity during the daily fluctuations of PV panels, in-home batteries are a potential solution. Ranjan Pal et al. (2016) propose energy storage devices as a possible solution to accompany renewable energy sources (such as the Powerwall battery for residences recently introduced by Tesla). These devices are environment friendly and a cost effective way to tackle this challenge. In addition, the capability of a storage can be exploited to shift energy across times. The increase in control during fluctuation in renewable energy generation lead to a power balance in the Smart Grid. Wurtz et al. (2017) provide at the level of micro-grid of the building an extra component in which the storage energy can be used for mobility by recharging batteries of electrical vehicles connected to home and dwellings. In a prosumer comm unity, storage devices can be implemented at the individual and collective level. However, individual in-home batteries are reasonable expensive, have a long payback time of 16 years and no subsidy can be claimed. Therefore, in-home batteries are still not financially attractive to invest in. The investment can be reduced by purchasing a large storage device by collective consumers for multiple dwellings or for the whole neighborhood. Today, these devices are not financially interesting, but there are factors in the future that will positively change the payback period. These factors are for example: rising energy prices, falling prices of in-home batteries, abolition of the 'salderen' policy after 2020 and the increase in feeling independent from large energy suppliers.

2.4.2 A SMART PROSUMER COMMUNITY

For the energy efficient implementations at the technical level, assumptions will be made regarding a prosumer community, both at the individual and collective level. At the collective level, the heating and cooling demand of a dwelling can be generated by an aquifer thermal energy storage system. However, in this research, it is not assumed that there is an operator that exploits land for a collective aquifer for elaborating a prosumer community. Therefore, it is assumed that each dwelling in a prosumer community has an individual closed-loop borehole thermal energy storage system for its own heating and cooling demand. In the individual closed-loop system, the heat and cooling is extracted by a heat pump. The electricity demand for the heat pump and the household consumption is mainly generated by solar panels that are implemented at each dwelling. Due to the imbalance during the day, the electricity of the solar panels is distributed to an in-home battery. The aim of the in-home battery is to provide energy to the community during non-peak hours.

In Figure 6, the concept of a prosumer community is visualized. As can be seen, dwellings are connected to the energy grid. This decentralized energy grid is used as a SMART energy grid in which dwellings exchange energy to each other, which is in line with the aim to keep the produced energy within the community. To improve the current energy net to a smart grid, SMART demand side software is installed to control the production and consumption of energy. This software controls the energy that is generated by solar panels and the current charge status of the batteries. When for example, the battery of dwelling A is charged by the solar panels of dwelling A, the system transports the remaining energy to the battery of dwelling B, which is for example not completely charged. In this way, dwelling A purchases its energy to dwelling B. The financial savings can be obtained by selling the energy in the community for at least 20% lower than the current energy prices. The assumption is that energy is only imported from the main energy grid by the community when all batteries are depleted and the energy generated by the solar panels cannot meet the energy demand. Especially, during winter periods, energy need to be imported from the main grid. In the figure, the energy connection to the main energy grid outside the decentralized community is visualized. The aim is to import as less energy as possible to avoid purchasing of more energy from the main energy grid. In this thesis, the ethical aspects and legal regulations of the consumer and market authority and energy network operator are not included, the focus is only on the technical feasibility at the individual and community level. In a prosumer community it is not mandatory to include all energy efficient implementations. However, it is required that households contribute to the community by supplying energy to the decentralized SMART grid. Still, an equally divided community with in-home batteries is essential to prevent too much importing of energy to the decentralized SMART grid. Households which do not apply all energy efficient measures, have lower initial investment costs, but are compulsory to purchase more energy from the grid.

By comparing this concept of a prosumer community with the existing literature, this concept broadly corresponds, but distinguishes itself in being full-electric powered. First, by focusing on how the heating and cooling demand is elaborated, dwellings in the PowerMatching City (Kesting & Bliek, 2013) include a small-scale combined heat and power(µCHP) unit that is powered by gas and in the Prosumer Community Denmark (Hansen & Hauge, 2017) bio-mass is used for heating and the cooling demand is met by an airco unit. In comparison to the borehole thermal energy storage system, the energetic efficiency of the BTES system is higher, no extra system need to be installed to overcome the cooling demand and no external sources (gas, biomass) have to be used. Furthermore, by focusing on the electricity generation, all concepts state that solar panels are the most suitable solution and need to be installed at the dwellings in the community. Moreover, storage devices are also included in the PowerMatching city to maintain the generated energy as much as possible within in the community. In both examples,

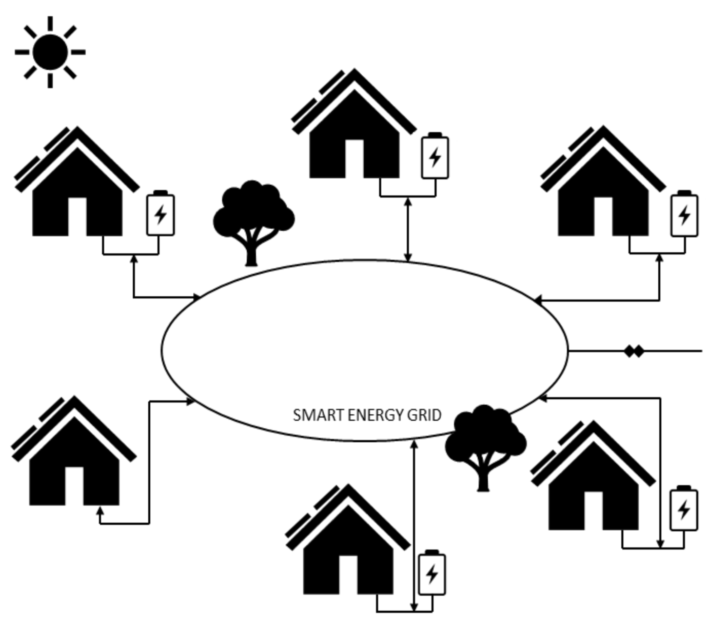

Figure 6 Prosumer community concept

demand side management software is installed in the community to manage the supply and demand of the energy. However, both examples also state that being complete independent from the main energy grid is not possible because of seasonal fluctuations that have a negative effect on the energy generated. All in all, the concept of a prosumer community described in this research adds a new elaboration to the existing literature in being full-electric powered to overcome the heating, cooling and electricity demand.

2.5 CONCLUSION

As stated in the literature, a prosumer community can contribute to the total share of renewable energy by producing energy and sharing the excess of energy generated with the grid and/or with other consumers in a community. By looking at the technical infrastructure of a prosumer community, the concept of smart grid is explained in the literature as a suitable solution. Smart grid is an advanced power system with integrated communication infrastructure to enable bi-directional flow of energy and information, which offers a greater monitoring and control of people's energy consumption. The detailed information can be obtained by smart metering infrastructure solutions. This system is capable of measuring energy consumption while providing more information than a conventional meter and that can transmit and receive data using a form of electronic communication. By gaining detailed information, people can evaluate their energy consumption and production profiles as prosumers. Due to these insights, consumers can be enticed to reduce their own energy consumption. Next to the energy-saving potential, there is a large potential for smart metering infrastructure. Additionally, the network operator can better control the supply and demand by using the detailed information of energy consumption and production. The objective of a prosumer community is to maintain the energy generated as much as possible in the community. By implementing demand side management software in a prosumer community, the production and consumption of energy in the neighborhood can be managed. When there is an excess of energy, prosumers can sell their energy to people who prefer sustainable energy. This system can be combined with storage devices, in which it becomes possible to store energy surplus. This reduces the need for importing energy from the main energy grid. Finally, a new concept of a prosumer community is introduced as an addition to the current literature. In this concept, the energy efficient implementations are determined by their high energetic efficiency, general suitability and future potential. Furthermore, based on the ambition of the Dutch government to become more independent from the gas, the implementations in the introduced prosumer community are full-electric powered. As can be concluded from the literature, prosumer communities are a potential solution to implement in future neighborhoods and can contribute to a new technical energy infrastructure.

3 FINANCIAL CONSEQUENCES

In the previous sections, knowledge has been gained regarding the technical potential of prosumer communities. In addition, multiple energy efficient implementations are proposed based on their high energetic efficiency and future potential. However, the financial consequences of these implementations are not considered. Therefore, this chapter provides the financial consequences and optimizations of a prosumer community, starting with the energy price expectations of the future. Next, the two investment scenarios which are investment by individuals or investment by an energy service company are analyzed according to their pros and cons. Finally, a financial analysis is conducted to compare the financial consequences of three scenarios: prosumer, BENG and EPC 0.4.

3.1 FUTURE ENERGY PRICE EXPECTATIONS

Table 4 shows the national energy exploration (NEV) of Dutch government in 2017 (Energieonderzoek Centrum Nederland (ECN), 2017). As can be seen, the prices of nonrenewable energy sources, such as gas, oil and coal, will rise in the future. Besides this rise, there is a fall in the gas extraction and the demand for gas in the next decades. The NEV expects that the Netherlands will switch from gas exporter to gas importer in 2025, due to the limited available gas. Furthermore, the fossil energy price will remain low to 2020, but after 2020 it is expected the prices will rise, because of the expected rising fuel prices in the future. The third remarkable fact is that the share of renewable energy sources is expected to exponentially increase in the next 20 years. Based on the intended policy, half of the installed electricity power in the Netherlands is generated by solar panels and wind turbines by 2023. In addition, it is also expected that the target of 2020 will not be accomplished, but the target of 2023 will be achieved. Finally, the results of the NEV shows that due to national policies, companies and households, the effort of energy-saving activities increases. This positive development will lead to a four percent in 2020 decrease compared to 2016 and almost 8 percent difference in the period of 2016 and 2030. In conclusion, rising energy prices for non-renewable energy sources will positively affect people's decision to invest in energy efficient implementations.

Table 4 Results National Energy Exploration 2017 (ECN, 2017)

	2000	2010	2017	2020	2030	2035
Bbp (index 2016=100)	83	94	100	108	128	137
Oil price (US$ per barrel)	41	88	44	53	111	118
Gas price (eurocent per m^3)	16	20	15	17	31	33
Coal price (euro per ton)	45	76	46	52	67	68
CO_2 price (euro/ton)	-	15	5	7	16	25
Wholesale electricity price (euro per megawatt hour)	58	53	34	32	44	48
Gross final energy consumption (petajoule)	2141	2352	2090	2000	1933	1871
Renewable energy (petajoule) (calculation method EU directive)	35	92	125	248	462	517
Share of renewable energy (percent) (calculation method EU directive)	1,6	3,9	6,0	12,4	23,9	27,6
Share of renewable energy (percent) (calculation method 'Actual production')	-	-	-	13,0	-	-
Energy-saving rate (percent per year)	-	1,1	-	1,7	0,9	-
Gas production (billion m3)	69	84	48	43	17	14
Gas demand (billion m3)	48	49	38	32	25	24

3.2 FINANCIAL INVESTMENT SCENARIOS

The realization of energy efficient prosumer communities is dependent on investments by households. The high initial costs are a decisive factor and constrain their decision. Therefore, two scenarios are provided with potential financial solutions to lower the threshold of people to invest.

3.2.1 Scenario A: investment by individuals

In the first scenario, the investment of the energy efficient implementations is realized by the local residents. Due to the expectations of rising energy prices, energy efficient implementations will be more financially attractive in the future for households. However, according to Frederiks et al. (2015), the immediate high financial costs for people to invest in energy-efficient house improvements (e.g. installing solar panels, insulation, low-energy appliances) may constrain people’s decision. Therefore, the financial threshold of people to realize the investment on their own, needs to be as little as possible. First, by realizing an investment collective as a community, scale benefits can be achieved. When people are aware of the scale benefits for their collective investment, they can positively influence their neighbors. By the increase of the collective tender, people gain more negotiation power, which is beneficial for the total investment. Secondly, people can also contract a loan focused for sustainable investments. For 2018, 100 percent is established as the maximum loan to value (LTV) for mortgage lending. However, when households invest in energy efficient implementations, a maximum of 106% LTV can be borrowed. The difference between this is called the Energy Savings Budget. This is the amount that someone can borrow extra, on condition that the budget is fully spent on energy efficient implementations (NHG, 2018). For households that will apply energy efficient implementations to their existing home there is an Energy Saving Loan (ESL). Homeowners can finance energy efficient implementations with this loan, such as better insulation or a new HE boiler or solar water heater. Solar panels can also be paid from the loan, but for a maximum of 75% (RVO, 2018). These arrangements supported by the Dutch governments lower the threshold for households to invest, because the high initial investment can be spread out over a longer period. In conclusion, energy efficient implementations improve the quality of the dwellings and will therefore positively affect the real estate value. For the rental corporations and institutional investors, the value of the housing stock maintains or is improved. Besides the advantage of the lower energy costs, energy efficient implementations contribute to a higher living comfort (Sweco, 2017).

3.2.2 Scenario B: Outsourcing of collective energy supply

To overcome the complexity of implementing energy efficient implementations at the district level, prosumer communities can outsource their activities by Energy Service Companies (ESCOs). According to Marino et al. (2010, p. 7), ESCOs can be defined as: “a natural or legal person that delivers energy services and/or other energy efficiency improvement implementations in a user’s facility or premises, and accepts some degree of financial risk in so doing”. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria”. According to Bertoldi et al. (2006), ESCOs can overcome the following barriers for energy efficiency and microgeneration:

- Lack of understanding of the saving opportunity;
- Lack of time to address energy, since energy forms a small portion of overall expenditure;
- Lack of capital, or a high cost associated with borrowing capital;

- A lack of capacity to install implementations;
- Consumers' and financial institutions' aversion to risk and to new technologies and service delivery routes;
- Issues associated with installation such as connection, metering, notification to network operators
- Difficulties in securing top-up and back up sources of electricity and heat (when demand is greater than output) and sale of surplus electricity to other customers (when output is greater than demand)

ESCOs can address these barriers by providing information, finance, installation, operation and maintenance under a long-term contract. An important motivation to cooperate with ESCO, is they can claim tax rebates (EIA/Vamil) and sustainable financing, in which an investment advantage of approximately 10% can be achieved (Sweco, 2017). Therefore, ESCOs are a potential supplier for prosumer communities when there is a need for technical execution and financial support.

3.3 CASE: FINANCIAL FEASIBILITY PROSUMER COMMUNITY

In this section, a financial analysis is conducted to compare the financial consequences of three scenarios: prosumer, BENG and EPC 0.4. Therefore, a mixture of energy efficient implementations related to each scenario is elaborated. In this analysis, a semi-detached dwelling of 150m2 is assumed. For this dwelling, the thermal efficiency and financial feasibility for energy efficient implementations are determined, not the architectural costs. Furthermore, only the investment by individuals is considered instead of financial optimizations by energy service companies (ESCO). The detailed structure of the financial analysis is based on assumptions retrieved from experts of Sweco and can be found in Appendix I: Financial analysis. This section starts with describing the structure of the model and the different assumptions followed by the elaboration of the three scenarios.

3.3.1 Energy demand Scenario's

To start with the financial analysis, it is of importance to gain insight in the energy demand of a semi-detached dwelling of 150 m2. In Table 5, the energy demand for heating, cooling and not building related energy consumption is presented, based on the Uniform Benchmark for Built Environment (UMGO) for the heat supply of buildings (Nuiten et al., 2017). According to this benchmark, the energy demand of an EPC 0.4 and BENG dwelling are identical for a semi-detached dwelling. It is assumed that the energy demand for a prosumer dwelling corresponds to the BENG requirements, because the BENG requirements represent the latest architectural requirements for a dwelling. For the calculations in the financial model, the heating and cooling are converted from kWh to Gigajoules, because by using this unit a distinction between m3 and kWh can be converted for the different scenarios.

Table 5 Energy demand semi-detached dwelling

Energy demand	Value	Unit	Total	Unit
Space heating	0.08	[GJ/m2]	11.29	[GJ/year]
Hot Tap water	0.05	[GJ/m2]	7.29	[GJ/year]
Cooling / summer comfort	0.01	[GJ/m2]	1.13	[GJ/year]
Auxiliary energy - fan, pump, parasitic lighting	3.90	[kWh/m2]	585.00	[kWh/year]
Equipment - electrically not building-related	19.90	[kWh/m2]	2,985.00	[kWh/year]

3.3.2 Parameters heat and cooling implementations for generation

The next step in determining the actual energy demand for the heating, cooling and electricity, the thermal efficiency per implementation needs to be calculated. The energetic efficiency is a ratio between the outgoing useful energy and the energy that goes into it, in which 100% thermal efficiency is the base. In Table 6, the assumptions for the thermal efficiency values per implementation are listed. As can be seen, there is a large difference in the thermal efficiency of the heating and cooling between the gas boiler and the borehole thermal energy storage system. With these units, the gas per m3 and electricity per kWh demand can be calculated for the heating and cooling demand. When for example calculating the space heating demand, the borehole thermal energy storage system has a energetic efficiency of 450%. This means that per kWh that goes into it, 4.5 kWh can be obtained. In contrast, by calculating the space heating demand for a gas boiler, the thermal efficiency is 90%. This means that per m3 gas that goes into it, 0.9 m3 gas can be obtained, which indicates that more m3 gas is necessary to meet the heating demand of the dwelling. Furthermore, the thermal efficiency of solar panels is presented including the efficiency decrease after 10 and 20 years. Finally, it is worthwhile to note that the electric efficiency of an in-home battery is 93%, because this implementation needs extra energy to charge and discharge. These thermal efficiency values are used to calculate the heating, cooling and electricity supply and demand in the three scenarios.

Table 6 Thermal efficiency heating, cooling and electricity

Thermal Efficiency	Efficiency (η)	Value
Implementations heating		
Space heating (Heat pump BTES system)	η thermal	450%
Hot Tap water (Heat pump BTES system)	η thermal	250%
Space heating (gas boiler)	η thermal	90%
Hot Tap water (gas boiler)	η thermal	80%
Implementations cooling		
Cooling / summer comfort (CKM)	η thermal	300%
Borehole thermal energy storage	η thermal	2000%
Implementations electricity		
PV panels	η thermal	100% 90% (after 10 years) 80% (after 20 years)
In-home battery	η electricity	93%

3.3.3 Financial parameters purchasing and selling of energy

When the energy demand for heating, cooling and not building related energy is determined, these amounts can be multiplied by the different energy prices. By focusing on the energy from the main energy grid, the energy price is divided in three categories: bare energy costs, energy tax and sustainable energy storage costs. In Table 7, the energy prices and their relative increase compared to the previous year are presented. The energy price expectations to 2050 are obtained from the input Excel model of Sweco, which can be found in Appendix I: Financial analysis. Per year, the energy that is demanded is multiplied by the energy price of gas (m3) and electricity (kWh). Furthermore, for scenario 3: Prosumer, it is assumed that the energy price purchased within the community is 20% lower than the actual energy prices to stimulate participating in a prosumer community by benefiting from lower energy prices.

Table 7 Energy price structure

	Unit	[Euro/kWh] 2018	[Euro/kWh] 2019	[Euro/m3] 2018	[Euro/m3] 2019
Bare energy costs	[Euro]	€ 0.1703	€ 0.1755	€ 0.2563	€ 0.2627
	[% increase relative to previous year]	2.00%	3.00%	2.50%	2.50%
Energy tax	[Euro]	€ 0.0527	€ 0.0543	€ 0.2600	€ 0.2756
	[% increase relative to previous year]	8.00%	3.00%	3.00%	6.00%
Sustainable energy storage	[Euro]	€ 0.0180	€ 0.0207	€ 0.0285	€ 0.0316
	[% increase relative to previous year]	46.00%	15.00%	79.25%	11.00%
Total	**[Euro]**	**€ 0.2411**	**€ 0.2505**	**€ 0.5448**	**€ 0.5700**
	[% increase relative to previous year]	**6%**	**4%**	**5.1%**	**5%**

In all scenario's, the calculation is based on the current 'salderen' policy up to 2020 and the expected feed-in fee when the 'salderen' policy is abolished. In the new policy, only the direct energy that is used from solar panels can be deducted by the 'salderen' policy. For the remaining indirect energy that is exported to the energy grid, a feed-in fee can be obtained. In the financial model, it is assumed that 30 percent of the energy of the solar panels is directly used and for the remaining 70 percent, a feed-in fee can be obtained. According to the announcement of the Minister for Economic Affairs and Climate (2018), the aim for the feed-in fee policy after 2020 is to maintain a seven years payback period for solar panels. In this research, an assumption is made regarding this statement. It can be expected that in this case, the feed-in fee will probably be 0.1525 euro per kWh. This assumption is based on the following calculations, in which the numbers are retrieved from experts of Sweco:

Investment 16 solar panels (incl. inverter and montage): 4,680 euro
kWh generation solar panels: 3,740 kWh
Payback period: 7 years

Energy used direct: kWh generation * percentage direct
3,740 * 30% = 1,122 kWh per year
Energy used indirect: kWh generation * percentage direct
3,740 * 70% = 2,618 kWh per year

Total financial savings: Investment costs / payback period
€ 4,680 / 7 = € 668.57 per year
Financial savings direct: Energy used direct * energy price
1,122 kWh * € 0.24 = € 269,28 per year

Remaining savings: Total financial savings - financial savings direct
€ 668.57 - € 269.28 = € 399.29 per year
Feed-in fee: Remaining savings per year / energy used indirect
€ 399.29 / 2,618 kWh = <u>€ 0.1525 per kWh</u>

Finally, all scenario's include the gas and electricity network operator costs, based on the prices of Tennet (Stedin, 2018). The gas network operator costs are € 107.46 per year and the electricity network operator costs are € 195.83. The gas network operator costs expire in scenario 2 and 3, because these scenarios are full electric.

3.3.4 Investment and maintenance costs

In Table 8, the investment and the maintenance costs per energy efficient implementation are presented. The investment costs correspond to the different scenario's in which in each scenario a different combination of implementations is used. As can be seen, the reinvestment costs for some implementations are included in the lead time of 25 years. Furthermore, the calculations for the financial analysis are based on a price index of 2% increase per year, except the costs for a heat pump, individual borehole and in-home battery. For these implementations, it is expected that these become less expensive in the coming years because of technological developments. Furthermore, the investment costs for demand side management ICT software is based on an assumption, because there is still no software package available.

Table 8 Investment and maintenance costs per implementation

Implementations	Initial Investment (€)	In year	Depreciation	Reinvestment in year	Maintenance (€)	Frequency in years
Gas boiler	€ 3,150	2018	15	2033	€ 130	1
Heat pump	€ 5,500	2018	15	2033	€ 140	1
Individual borehole	€ 12,000	2018	30	2048	-	1
CKM.	€ 1,250	2018	15	2033	€ 150	1
Inverter	€ 680	2018	15	2033	-	1
PV panels	€ 4,000	2018	25	2043	€ 50	1
In-home battery	€ 5,500	2018	15	2033	-	-
ICT software	€ 1,000	2018	-	-	-	-

3.3.5 Financial scenario analysis

In this section, a financial scenario analysis is conducted to gain insight in the financial consequences of an EPC 0.4 dwelling, BENG dwelling and a prosumer dwelling. The objective of this analysis is to compare the investment and exploitation costs of the current requirements (EPC 0.4), the requirements from 2020 (BENG) and the prosumer scenario. This results in a financial overview of the different scenarios to decide which scenario is the most financially suitable. The exploitation period in all scenarios is 25 year, which is based on the depreciation of the solar panels. In Appendix I: Financial analysis, the detailed structure of the financial model is provided to estimate the effect of the expected two years remaining 'salderen' policy and how the feed-in fee can be elaborated. In addition, the complete cashflow calculation and financial differences between each scenario can be found in Appendix I: Financial analysis.

Scenario 1: EPC 0.4

In the first scenario, the financial consequences for an EPC 0.4 dwelling are elaborated. According to the Uniform Benchmark for Built Environment (UMGO) (Nuiten et al., 2017), the EPC 0.4 requirements are the requirements for dwellings which have been built between 2015 and 2020. In these requirements, the following energy efficient implementations are prescribed: gas boiler, cooling machine and 16 solar panels. The financial consequences of this scenario are provided in Table 9. As can be seen, the abolition of the 'salderen' policy has a substantial impact on the total energy purchasing costs, but from this point revenues by the feed-in fee can be obtained. It is worthwhile to note that the decrease of the feed-in fee can be explained by the decrease in efficiency of solar panels as described in section 4.3.2. Furthermore, the total energy purchasing costs increase over the years because of the expected gas price increase of 200%. By focusing on the investment, the first investment is realized in year 0 and the re-investment of the gas-boiler, CKM and the inverter of the solar panels is realized at the start of year 16. The details of the financial analysis structure and the complete cashflow can be found in Appendix I: Financial analysis.

Table 9 Financial consequences scenario EPC 0.4

	Year 0	Year 1	Year 2	Year 3	Year 14	Year 15	Year 16	Year 23	Year 24	Year 25
		2018	**2019**	**2020**	**2031**	**2032**	**2033**	**2040**	**2041**	**2042**
Total energy purchasing		€ -423	€ -443	€ -1,144	€ -1,575	€ -1,601	€ -1,619	€ -1,607	€ -1,595	€- 1,590
Total revenues		€ -	€ -	€ 410	€ 369	€ 369	€ 369	€ 328	€ 328	€ 328
Gross margin		**€ -423**	**€ -443**	**€ -734**	**€ -1,206**	**€ -1,232**	**€ -1,250**	**€ -1,279**	**€ -1,267**	**€ -1,262**
Operational expenses		€ -542	€ -554	€ -564	€ -702	€ -716	€ -731	€ -839	€ -856	€ -873
EBITA		**€ -966**	**€ -996**	**€ -1,299**	**€ -1,908**	**€ -1,948**	**€ -1,980**	**€ -2,118**	**€ -2,123**	**€ -2,135**
Total investment	€-9,080						€ -6,837			
Cashflow	**€-9,080**	**€-966**	**€ -996**	**€ -1,299**	**€ -1,908**	**€ -1,948**	**€ -8,818**	**€ -2,118**	**€ -2,123**	**€ -2,135**

Scenario 2: BENG

In the second scenario, a financial analysis is conducted for a dwelling based on the BENG requirements. Compared to scenario EPC 0.4, this scenario has no connection to the gas network and the energy efficient implementations are full-electric. To meet the heating and cooling demand, an individual borehole thermal energy storage system is realized instead of the gas boiler and cooling machine. Furthermore, this scenario also includes 16 solar panels for electricity generation. In Table 10, the financial consequences of a BENG dwelling are presented. As can be seen, there are multiple changes compared to the EPC 0.4 scenario. First, the energy purchasing costs are lower than the EPC 0.4, because it is expected that the electricity prices be more stable than the gas prices. Secondly, the operational expenses of this scenario are lower than the EPC 0.4, because of lower maintenance costs and no network operator costs for gas. However, the investment costs are reasonably higher than the EPC 0.4 dwelling, which mainly can be attributed to the expensive realization of the individual borehole and the investment costs of a heat pump. The re-investment of this scenario includes a new heat pump and inverter for the solar panels and are indexed to the year 2034. The calculation details of the financial analysis regarding the BENG requirements can be found in Appendix I: Financial analysis.

Table 10 Financial consequences scenario BENG

	Year 0	Year 1	Year 2	Year 3	Year 14	Year 15	Year 16	Year 23	Year 24	Year 25
		2018	**2019**	**2020**	**2031**	**2032**	**2033**	**2040**	**2041**	**2042**
Total purchasing		€ -335	€ -349	€ -1,045	€ -1,391	€ -1,409	€ -1,418	€ -1,283	€ -1,254	€ -1,235
Total revenues		€ -	€ -	€ 411	€ 369	€ 369	€ 369	€ 328	€ 328	€ 328
Gross margin		**€ -335**	**€ -349**	**€ -634**	**€ -1,022**	**€ -1,040**	**€ -1,048**	**€ -954**	**€ -925**	**€ -906**
Operational expenses		€ -315	€ -321	€ -327	€ -407	€ -415	€ -424	€ -486	€ -496	€ -506
EBITA		**€ -651**	**€ -670**	**€ -962**	**€ -1,429**	**€ -1,455**	**€ -1,472**	**€ -1,441**	**€ -1,422**	**€ -1,413**
Total investment	€ -22,180						€ -6,415			
Cashflow	**€ -22,180**	**€ -651**	**€ -670**	**€ -962**	**€ -1,429**	**€ -1,455**	**€ -7,887**	**€ -1,441**	**€ -1,422**	**€ -1,413**

Scenario 3: Prosumer

Finally, the financial analysis for the third scenario: prosumer is conducted. In this scenario, three energy efficient implementations are realized: solar panels, borehole thermal energy storage system and an in-home battery. This results again in a full electric alternative in which there is no gas demand. The main difference of this scenario compared to the other scenario's is that this scenario includes an in-home battery for the storage of energy and a demand side management ICT software to control energy demand and supply in the prosumer community. As described in section 3.3.3 individual storage device, in-home batteries can overcome daily fluctuations of PV panels, by storing the residual electricity during the day. This means that less energy from the grid needs to be imported. Furthermore, when the battery is loaded, the remaining energy can be transported to other batteries in the community. By using this system, the generated energy is maintained into the prosumer community, which becomes more self-providing. In the financial model, it is assumed that 30 percent (1,122 kWh) of the solar panels is directly used and the remaining 70 percent (2,618 kWh) is used for the in-home battery. From this 70 percent (2,618 kWh), 80 percent (2,094 kWh) is used for own consumption and 20 percent (524 kWh) of the energy is purchased to other dwellings in the prosumer community, because it is assumed that not all dwellings in a prosumer community have installed an in-home battery. In addition, it is assumed that the energy consumption per household will differ because of different household compositions. Furthermore, the efficiency of an in-home battery is 93 percent, which means that an additional 183 kWh of energy need to be extra generated. Because the prosumer scenario is more complex, the assumptions and the structure of the energy demand can be found in Table 11.

Table 11 Energy demand prosumer

ENERGY DEMAND	Unit	Total energy demand
Gas m3 space heating	[m3/year]	-
Gas m3 hot tap water	[m3/year]	-
Total gas demand	**[m3/year]**	**-**
Electricity space heating	[kWh/year]	696.67
Electricity hot tap water	[kWh/year]	810.00
Electricity cooling / summer comfort	[kWh/year]	56.70
Auxiliary energy - fan, pump, parasitic lighting	[kWh/year]	585.00
Equipment - electrically not building-related	[kWh/year]	2,985.00
PV installation total	[kWh/year]	-3,740.00
PV installation – own usage (direct: 30%)	[kWh/year]	-1,122.00
PV installation – in-home battery (indirect: 70%)	[kWh/year]	-2,618.00
In-home battery electricity usage	[kWh/year]	183.26
In-home battery – own usage (80%)	[kWh/year]	-2,094.40
In-home battery – purchase community (20%)	[kWh/year]	-523.60
Total electricity demand	**[kWh/year]**	**2,100**

The financial consequences of a prosumer dwelling can be found in Table 12. Compared to the EPC 0.4 and BENG scenario, the total energy purchasing costs are reasonably lower. Furthermore, the total revenues consist of the purchasing of the stored energy to other dwellings in the community instead of exporting the remaining energy to the grid and obtaining a feed-in fee. To stimulate participating in a prosumer community, the energy is purchased for 80 percent of the actual energy prices. This results in a financial saving for other people in the community of 20%, which is for the purchaser more than the feed-in fee of 0.1525 euro per kWh. Moreover, the operational expenses of a prosumer dwelling are the same as the BENG scenario, because an in-home battery needs no maintenance. However, the investment costs for a prosumer are higher compared to the other scenarios as well as the re-investment costs. The detailed calculations of the prosumer scenario can be found in Appendix I: Financial analysis.

Table 12 Financial consequences prosumer scenario

	Year 0	Year 1	Year 2	Year 3	Year 14	Year 15	Year 16	Year 23	Year 24	Year 25
		2018	**2019**	**2020**	**2031**	**2032**	**2033**	**2040**	**2041**	**2042**
Total purchasing		€ -506	€ -526	€ -547	€ -811	€ -821	€ -826	€ -820	€ -802	€ -789
Total revenues		€ 101	€ 105	€ 109	€ 127	€ 129	€ 130	€ 328	€ 328	€ 328
Gross margin		**€ -405**	**€ -421**	**€ -438**	**€ -684**	**€ -693**	**€ -697**	**€ -719**	**€ -702**	**€ -691**
Operational expenses		€ -315	€ -321	€ -327	€ -407	€ -415	€ -424	€ -486	€ -496	€ -506
EBITA		**€ -720**	**€ -742**	**€ -765**	**€ -1,091**	**€ -1,108**	**€ -1,120**	**€ -1,205**	**€ -1,199**	**€ -1,198**
Total investment	€ -28,180						€ -11,415			
Cashflow	**€ -28,180**	**€ -720**	**€ -742**	**€ -765**	**€ -1,091**	**€ -1,108**	**€ -12,535**	**€ -1,205**	**€ -1,199**	**€ -1,198**

3.3.6 Cashflow scenario comparison

In Table 14, the cashflows of the three scenarios are compared in which the extra initial investment, direct savings per year, and the payback period are presented. In addition, the Table 13 shows the internal rate of return over 25 year. First, by focusing on the BENG dwelling compared to the EPC 0.4 dwelling, the average savings per year are €486 excluding the investment and re-investment costs. However, when including the extra-investment of the energy efficient implementations, the internal rate of return is negative: -0.27%. Despite the substantial savings per year, the payback period is expected to be in year 26. However, in this year the solar panels need to be replaced in which a re-investment is necessary. It can be concluded, that a BENG dwelling including a borehole thermal energy storage system is not financial feasible. The complete cashflow comparison can be found in Appendix I: Financial analysis.

Subsequently, the prosumer scenario is compared to the EPC 0.4 scenario. As can be seen, higher financial savings per year can be obtained, which are on average €744 excluding the investment and re-investment costs. However, the large initial investment and the interim re-investment results in a negative internal rate of -2.06%. Furthermore, after an exploitation period of 25 years, the payback period of the prosumer scenario is not achieved.

Table 13 Internal rate of return (IRR) scenarios

Scenario	IRR
BENG – EPC 0.4	-0.27%
Prosumer – EPC 0.4	-2.06%
Prosumer – BENG	-8.60%

Finally, by comparing the prosumer scenario to the BENG scenario, an average financial saving per year of €257 excluding the investment and re-investment costs can be obtained. This results in an internal rate of return of -8.06%, which means that the prosumer cannot be made financial feasible compared to the BENG scenario.

Table 14 Scenario comparison

Scenario comparison	Year 0	Year 1	Year 2	Year 3	Year 14	Year 15	Year 16	Year 23	Year 24	Year 25
		2018	**2019**	**2020**	**2031**	**2032**	**2033**	**2040**	**2041**	**2042**
BENG – EPC 0.4	€ -13,100	€ 315	€ 326	€ 337	€ 479	€ 493	€ 931	€ 677	€ 701	€ 722
BENG – EPC 0.4 cum.	€ -13,100	€ -12,784	€ -12,457	€ -12,120	€ -7,567	€ -7,074	€ -6,144	€ -1,945	€ -1,245	€ -522
Prosumer – EPC 0.4	€ -19,100	€ 246	€ 254	€ 533	€ 817	€ 840	€ -3,718	€ 913	€ 924	€ 937
Prosumer – EPC 0.4 cum.	€ -19,100	€ -18,853	€ -18,599	€ -18,066	€ -10,357	€ -9,516	€ -13,234	€ -6,940	€ -6,015	€ -5,078
Prosumer – BENG	€ -6,000	€ -69	€ -72	€ 196	€ 338	€ 347	€ -4,649	€ 236	€ 223	€ 215
Prosumer – BENG cum.	€ -6,000	€ -6,069	€ -6,142	€ -5,945	€ -2,789	€ -2,442	€ -7,090	€ -4,994	€ -4,770	€ -4,556

The results of the cashflow comparison of the three scenario over 25 years are visualized in Figure 7. In this figure, the bars present the investment costs and direct savings per year and the lines presents the cumulative payback period with year 0 as a starting point. As can be seen, none of the scenarios reach the break-even point in 25 year mainly because of the large initial investment and re-investment costs. According to these comparisons, it can be concluded that a prosumer dwelling is not financial feasible compared to the current EPC 0.4 and BENG requirements.

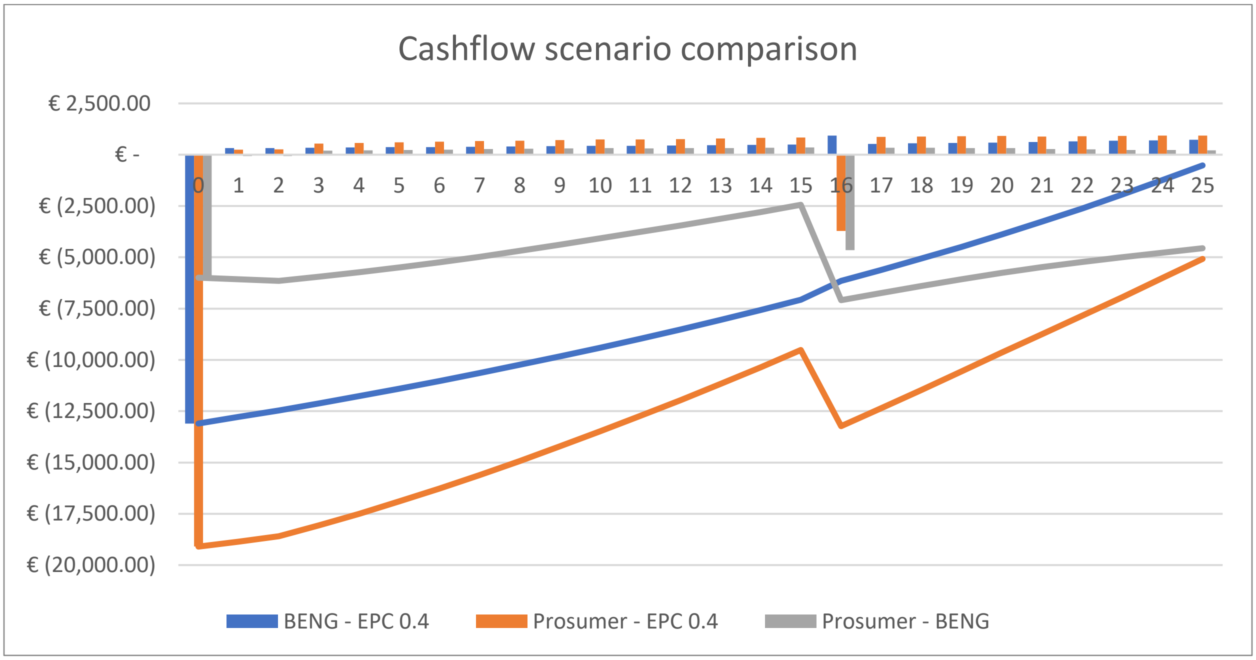

Figure 7 Cashflow scenario comparison

3.4 CONCLUSION

The objective of this chapter was to gain insight in the financial consequences pertaining a prosumer community. At first, it can be concluded that according to the energy price expectations, the gas price and the fossil energy price will rise in the future. Due to these rising prices, investing in energy efficient implementations becomes more financial attractive on a long term. To overcome the high initial investment costs, it can be concluded that there are two approaches: investment by individuals or outsourcing by an ESCO. Collective investments by individuals result in more financial savings and negotiation power. When people do not have the financial resources or knowledge to realize energy efficient implementations at their dwelling, ESCO outsourcing can be a potential solution. By applying this approach, the ESCO company takes the financial risk and people can be satisfied by generating their own renewable energy. However, the financial consequences of an ESCO are not considered in this research. In order to provide a complete substantiated overview of the financial consequences, a financial analysis has been executed for an EPC 0.4 dwelling, a BENG dwelling and a prosumer dwelling. The BENG and prosumer scenarios have been compared to the current EPC 0.4 requirements. As can be concluded from the financial analysis, reasonable financial savings can be obtained in the BENG and prosumer scenario by implementing a borehole thermal energy storage system. However, because of the high initial investment and re-investment costs, these scenarios are not becoming financial feasible compared to a dwelling based on the current EPC 0.4 requirements. This indicates that a dwelling in the future scenario by having an alternative for gas, is still not financial feasible because of current gas prices. The financial feasibility of participating in a prosumer community is dependent on the exponential rising of gas prices, the decrease in initial investment costs of a borehole thermal energy storage system and in-home battery, and the encouragement of the Dutch government by subsidies to invest in high thermal efficiency implementations. All in all, when deciding to invest in high thermal efficiency implementations for future dwellings, the pro-environmental attitude and the willingness to generate renewable energy should be more a decisive motivation for individuals to participate in a prosumer community than looking at the financial feasibility.

4 INDIVIDUAL ENERGY BEHAVIOR

As discussed, generated non-renewable energy sources are responsible for most greenhouse gas emissions that causes climate change. Therefore, on a global scale, researchers and policy makers are looking extensively for new cost-effective solutions and new technology to increase household efficiency and conservation (Frederiks et al., 2015). These energy efficient implementations are required to reduce the extensive emissions of greenhouse gases, yet their net benefits have been overestimated. The world's energy-related problems cannot only been solved by technological advances, but changes in human energy behavior are essential. However, only little attention is paid to energy behavior of individuals. This behavior of individuals needs to be shifted towards a more efficient and sustainable direction. Therefore, it is necessary to understand people's energy consumption and decisive motivations in order to provide insights in how these behaviors can be altered in a more energy efficient way.

This chapter begins with an overview of theoretical perspectives from the literature that describes the integrated key insights of individuals' energy behavior. According to Han et al. (2013) and Yue et al. (2013), energy-saving behavior can be divided to two categories: investment behavior and curtailment behavior. Investment behavior is the behavior of investing in technical equipment to reduce energy usage and increase the quality of the dwelling in terms of energy efficiency. Investment behavior involves a one-time purchase decision in which the financial feasibility by monetary savings is considered (Han et al., 2013). In addition, consumers are willing to invest more in appliances with energy efficiency labels (Yue et al, 2013). The second behavior that is considered is the curtailment behavior. According to Han et al. (2013), curtailment behavior entails with routines and habitual behavior of people. In order to achieve energy savings with curtailment behavior, people can reduce the usage of existing equipment's or appliances by behavior changes, such as shortening shower duration, switching of light, lowering thermostat setting, etc. Such changes in energy consumption behavior requires alteration of lifestyle in which people mostly choose to decrease their comfort. However, there is a limitation in considering both behaviors. When people apply an investment behavior, it is more likely that people think this investment will result in lower energy consumption. Therefore, people can be less careful about their energy consumption. This phenomenon is called rebound effect (Gillingham et al., 2016). To avoid this phenomenon, awareness in people's energy consumption should be monitored.

According to the literature (Abrahamse et al., 2009; Frederiks et al., 2015; Wang et al., 2011; Yue et al., 2013), there are three categories of variables that can be identified as essential for explaining the variability in energy behavior of individuals: socio-demographic characteristics (e.g. income, education, household size and home-ownership), psychological factors (e.g. beliefs and attitudes, motives and intentions, perceived behavioral control and cost- benefit appraisals) and contextual forces (e.g. government regulations). These variables can be assigned as the most influential variables on people's energy behavior.

4.1 SOCIO-DEMOGRAPHIC CHARACTERISTICS

The first category of energy behavior that needs to be considered is about the socio-demographic factors of individuals. Literature suggests that socio-demographic characteristics either at individual level or household level are influential on energy-related behavior. In general, socio-demographic factors set opportunities and constraints for people's behavior. In terms of energy behavior, these opportunities and constrains may have an influence on the amount, frequency and duration of people's energy use.

4.1.1 Socio-demographic characteristics

According to the research examined, the following effects from socio-demographic characteristics on energy behavior can be provided.

- *Gender*

From the findings of Frederiks et al. (2015), it seems that the effect of gender differences on energy consumption is inconsistent or minimal. Furthermore, some research indicate that women have a more pro-environmental behavior than men, while other research find no significant relationship (Frederiks et al., 2015) .

- *Age*

According to the results of Yue et al. (2013), people between 31 and 45 years old are the most willing to adopt an investment behavior. This is caused by their ability to pay for energy-efficient implementations and awareness of their advantages. In addition, it seems that younger people seems to have a more curtailment energy-saving behavior because of their limited monetary sources. Finally, it seems that older people are less likely to invest in energy efficient implementations, which might be caused by negative perceptions of cost/benefit ratio and return on investment. Furthermore, by looking of the life cycle of households, mid-life households have more energy requirements than younger and older households. This can be contributed that both households tend to live smaller with higher energy consumption per capita (Frederiks et al., 2015).

- *Household income*

Poruschi and Ambrey (2016) stated that household income has a positive potential on the energy preserving behavior of people. The amount of income can create opportunities to invest in substantial energy efficiency implementations (e.g. installation of solar electricity and/or solar hot water systems). The economic feasibility by applying energy efficient implementations and daily saving behavior will lead to savings on the energy bill. Frederiks et al. (2015) underlined the statement that household net income has a significant effect on investments in products and improvements that increase energy efficiency. In addition, Frederiks et al. (2015) stated that household income tends to be positively related to residential energy consumption, which means that increase in income causes more energy consumption. Finally, according to the research of Yue et al. (2013), people who have a low income are more willing to adopt energy curtailment behavior, while people with a high income are more willing to adopt energy investment behavior.

- *Education*

According to Frederiks et al. (2015), education seems to be associated with increased knowledge, awareness and concern regarding environmental issues. However, higher levels of education does not significantly lead to a more pro-environmentally behavior. Yue et al. (2013) underlined the above statement by concluding in overall, the current level of education does not produce a significant positive effect on energy saving. However, Das et al. (2018) stated that the effect of a university level of education on energy-saving technology adoption is larger than the effect of people who have high school or vocational level of education. In addition, Sardianou and Genoudi (2013) examined the willingness of people to implement energy efficient measures is higher by more educated individuals than by less educated individuals.

- *Household size and composition*

The variable household size can also be described as the number of people per residence. Frederiks et al. (2015) stated that household size is contributed to be positively associated with energy consumption, in which larger families does consume on average more energy. This is caused by the increase in frequency of activities over the week (e.g. washing, tumble drying and refrigeration) (Han et al., 2013). However, by looking at the energy usage per capita, it appears to be lower in larger households, presumably due to the energy sharing among multiple residents. By focusing on household composition, Yue et al. (2013) stated that households consisting of couples and children are more willing to adopt an energy curtailment behavior because of higher living and energy expenses.

- *Home-ownership*

According to the research of Frederiks et al. (2015 and Poruschi et al. (2016), most researchers conclude that homeowners are more willing to realize a larger investment in energy efficient implementations (e.g. household improvements to reduce energy usage, purchase of new technology and energy-saving devices) than people who are living in rental housing. This is caused by property rights for both permit and incentivize households to engage in more significant, longer term energy-saving behaviors (e.g. solar electricity).

- *Family life cycle stage*

Stage of family life cycle influences levels and patterns of household energy consumption and appears to be an important variable in explaining the household energy use. It seems that the energy consumption is peaking during child-rearing years, this is caused by the increase in household work (e.g. cleaning, cooking, laundry), childcare and family recreation (e.g. in-home entertainment, recreation) (Frederiks et al., 2015). This phenomena might change over time when for example a child is leaving home.

4.2 PSYCHOLOGICAL FACTORS

Despite the importance of socio-demographic characteristics on the energy-saving behavior of people, psychological factors have also a powerful effect. Therefore, in this review, three main psychological factors are considered: environmental awareness, decisive motivations and subjective norm.

4.2.1 Attitude and awareness

According to Wang et al. (2011), attitude refers to the degree of people's pro-environmental awareness of performing sustainable behavior. This behavior contributes to energy curtailment or/and energy investment behavior of people. Barreto et al. (2014) underlined this statement and added that it has been shown that most people are concerned about future generations access to renewable sources, which influences their attitude. In addition, Frederiks et al. (2015) describes that has been shown that people with a greater knowledge, awareness and understanding of the environmental issues tend to have a more pro-environmental attitude. This perspective has also been supported by Zografakis et al. (2010), who stated that people are more willing to invest in energy efficiency implementations and participate in energy-saving activities when they have a stronger awareness of the global climate change. Lin (2015) describes the more an individual has an intention to engage in a certain behavior, the more likely this behavior will occur. However, Frederiks et al. (2015) argues that environmental attitude might lead to positive intentions towards an energy-saving behavior, but intentions can be obstructed from being realized into actual behavior. Intervening factors are for example: lack of knowledge, social norms, perceived personal responsibility, cost-benefit trade-offs, situational and institutional factors. This phenomena lead to an "attitude-action gap" in which people are aware of the climate change problem, but fail to translate this attitude into practical actions to limit household energy use (Frederiks et al., 2015). To gain more insight in the decisive factors that creates a gap between the attitude and action, willingness of people to behave in a certain way need to be considered. Silvia et al. (2008) adopted in their research a choice experiment to evaluate the consumers' willingness to pay for energy efficient implementations (WTP). The results show that the WTP is on average higher than the costs of implementing energy efficient implementations. However, there are still some barriers that hold people from it. These barriers are for example legal, structural or socio-economic barriers. Silvia et al. (2008) assumed that these barriers are caused by a lack of information regarding the advantages and the methods to implement energy efficient implementations. Therefore, providing sufficient information to people increases their awareness and may decrease the attitude-action gap.

4.2.2 Decisive motivations

As defined by Frederiks et al. (2015, p. 16), motivations are "the driving forces or impulse that initiate, guide and maintain goal-directed behavior; that is, the specific reasons why a person acts in a certain way at any given time". Motivations are driven by intensity, direction and persistence of effort that a person allocates towards achieving a specific goal. The process of performing a specific behavior largely depends on the degree of perceived behavioral control in which the costs and benefits are weighted (Wang et al., 2011). In general, according to Frederiks et al. (2015), people are less likely to behave pro-environmental which is inefficacious and "does not make a difference". Therefore, adopting a pro-environmental behavior must be effective in yielding valued outcomes. By yielding the valued outcomes, people are more motivated by self-interest and engaging in energy-saving behavior resulting in the highest benefits and the lowest costs. The cost-benefit tradeoffs include also valued resources as: time, effort, social status/acceptance, convenience and comfort (Frederiks et al., 2015). By looking at the evidence in literature, the most decisive motivations are monetary incentives and increase in personal comfort.

First, according to Frederiks et al. (2015), the immediate high financial costs for people to invest in energy-efficient house improvements (e.g. installing solar panels, insulation, low-energy appliances) may constrain people's decision. Therefore, the long-term monetary payoffs play an important role in this process. However, energy usage costs have a reasonable impact on the energy bill of homeowners and might therefore be more motivated to reduce their energy consumption. In addition, Wang et al. (2011) underlined that financial benefits have a significant influence on energy-saving behavior. To stimulate this behavior, Frederiks et al. (2015) suggest that an increase in energy prices may have a positive impact on consumers to invest in energy efficient implementations that will yield energy savings. However, monetary incentives by government programs can also have a positive influence on people's investment behavior. Das et al. (2018) examined that the driving force for people of implementing energy efficient implementations in their dwelling may not rise from income, but from monetary incentives provisioned. The researchers therefore recommend to encourage the adoption of energy efficient implementations by offering monetary incentives. There are two types of monetary incentives that can be provisioned to customers. Sardianou and Genoudi (2013) found that tax reduction is slightly more effective for people than an energy subsidy as an effective financial incentive for people to adopt energy efficient implementations. Still, both incentives are preferred by people and governments should encourage them.

The second decisive motivation for people is the need for personal comfort (e.g. thermal comfort, air quality and noise protection) (Barreto et al., 2014; Frederiks et al., 2015; Wang et al., 2011). The essence to maintain a comfortable house is for many people decisive. Especially, the perceived loss of comfort that is imposed by a particular energy efficient measure has a sizable impact on household energy activities (Frederiks et al., 2015). Barreto et al. (2014) explain this with an example: “Families who referred to this motivation, wanted, for instance, to control the thermostat to be able to maintain comfortable temperature at all times”. In the literature, people in general less willing to apply curtailment behavior because it requires more effort (decrease in comfort). However, according to Barr et al. (2005) less than a quarter of non-environmentalists is willing to sacrifice some comfort to save energy, whilst over 60% of committed environmentalists is willing to do so. Furthermore, Frederiks et al. (2015) found that comfort is related to energy consumption in both summer and winter seasons and that comfort accounts for 30% of the variability of households energy consumption.

4.2.3 Subjective norm

Subjective norm is defined by Lin (2015, p. 4) as: “perceived social pressure and is based on an individuals’ perception of whether other important people in their life would want them to perform a behavior”. Therefore, subjective norm can influence an individual to perform an energy-saving behavior or even to invest in energy efficient implementations. According to Yue et al. (2013), group-level feedback and peer education can modify people’s energy behavior even without receiving an economic reward. Barreto et al. (2014) examined that people are more willing to modify their behavior when the impact becomes visible to their social network. This expression is in line with social influences, such as peer pressure, public accountability and competition. Frederiks et al. (2015) added that intrapersonal sources of information appears to be more influential to people than media appeals in eliciting and sustaining reductions in energy use. In addition, even a personal opinion or actions from a friend on energy choices is more influential than being adviced by an expert, which is better informed.

4.3 CONTEXTUAL FORCES

Individual behavior can also be influenced by contextual forces, such as government regulations or public policies. Frederiks et al. (2015) describes that these macro-level factors place constraints on policymakers, who will have to compose relatively fixed societal and institutional boundaries in their public policy decisions for the energy industry and consumers. According to Kuh (2012), law and policy can be used to change how individuals impact their environment through their behaviors and lifestyles. Therefore, environmental law and policy is required to balance government privilege with individual liberty. Kuh (2012) distinguished direct and indirect regulated behavior with the following examples: “A subsidy for hybrid vehicles is a regulation of the market that indirectly regulates the harms imposed by individual driving behavior. Smart-growth zoning, designed to reduce car travel, is a direct regulation of architecture that indirectly regulates individual driving behavior" (Kuh, 2012, p. 6). It can be concluded that policy and regulations are required to influence individual energy curtailment and investment behavior and will therefore encourage people to change their lifestyle. Policy and regulations might also positively influence people's decision to become prosumers and participate in a prosumer community.

4.4 ADOPTION OF INNOVATION

The definition and elaboration of a prosumer community can be seen as innovative within the residential sector. Because the success or failure of this innovative product depends on the responses of potential customers in the marketplace, it is important to gain insight in the adoption and diffusion of people towards innovations. Rogers (1995) developed the technology adoption cycle and diffusion theory to define how markets develop for innovations, based on socio-demographic and psychological characteristics. As can be seen in Figure 8, the bell-shaped curve divided the whole market into five category of potential customers, starting with the innovators. The innovators are technology enthusiastic, are open to change and intrigued by the technology and its opportunities (Nijssen, 2017). Innovators constitute the smallest percentage of risk-immune, but are the most willing to change their behavior. The next category consist of the early adopters that are more willing to adopt new innovations faster than the majority, but do not behave on the front lines of innovation. The customers from the first two categories can be identified as the most potential group to participate in a prosumer community. However, these groups are as little as 16 percent of the total population according to this model. The third and fourth categories represents the majority of potential customers in the market and consist of the largest population percentage. The early and late majority have an average risk propensity and moderate attitude, and thus an average willingness to change (Nijssen, 2017). The early majority consist of people that are more pragmatic and wait before the technology has proven itself. In contrast, people in the late majority only implement the technology when they have to. The final category on the right side are the most skeptical people that represents the laggards. The laggards are hesitant to change and prefer to avoid the adoption of new technology or innovations as long as possible (Nijssen, 2017). For this research, the investment behavior of people in energy efficient innovations as the adoption of a more energy curtailment behavior based on socio-demographic characteristics, can be classified in this model. For example, by looking at the innovativeness of a prosumer community, the enthusiasts and visionaries seems to be the main target group. When it turns out that this new concept is beneficial and useful, the large group of pragmatists can be convinced. To persuade the late majority, policy makers might have an important role to speed up this process by tighter regulations on non-renewable energy usage and encouraging renewable energy developments.

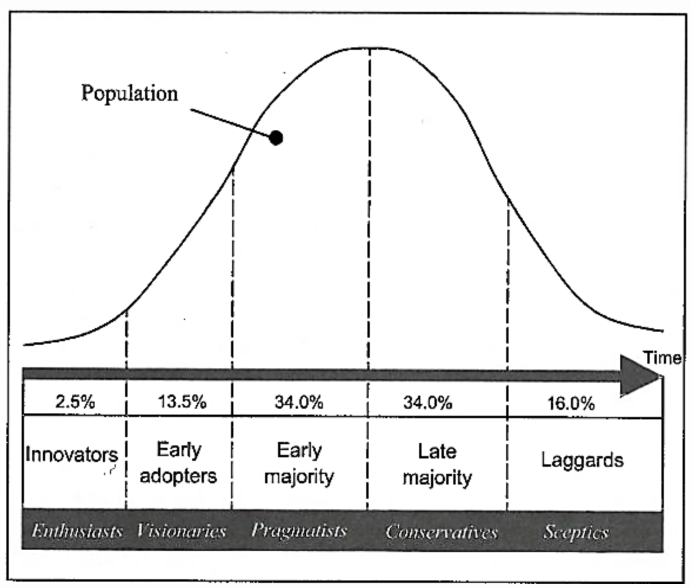

Figure 8 Technology adoption life cycle (Nijssen, 2017)

4.5 CONCLUSION

It can be realized that the world energy-related problem cannot only be solved by technological advances, but changes in human energy behavior are essential. By focusing on the energy behavior of people, two categories can be considered as important: curtailment behavior and investment behavior. The curtailment behavior focusses more on the energy saving by reducing the usage of existing equipment and appliances. In contrast, investment behavior focusses on investing in technical equipment to reduce energy usage and increase the quality of the dwelling in terms of energy efficiency. Both behaviors can lead to the phenomenon rebound effect in which an increase in energy efficiency may lead to less energy savings than would be expected by simply multiplying the change in energy efficiency by the energy use prior to the change (Gillingham et al., 2016). To avoid that, monitoring and measuring should be integrated to such behavior as well.

According to the literature, three factors can be identified in explaining the variability of people's energy behavior. First, the socio-demographic characteristics of individuals are influential on their energy behavior. In the literature, there is a lot of support on the following socio-demographic characteristics: gender, age, income, education, household size, home-ownership and family life cycle stage. To complete the objective of this research, these factors are explained and need to be implemented in the choice experiment design. Secondly, the psychological characteristics including environmental attitude and awareness, decisive motivations and subjective norm can be considered as the most influential factors on individuals' investment and curtailment behavior. Concerns about climate change and future generations positively lead to a more pro-environmental attitude. Additionally, the level of knowledge on the climate problem and energy efficient implementations plays an important role. When looking at the decisive motivations, it can be concluded that adopting an investment or curtailment behavior must be effective in yielding valued outcomes. According to this conclusion, people are more motivated by self-interest and engaging in energy-saving behavior resulting in the highest benefits and the lowest costs. In the literature, the cost-benefit tradeoff significantly impacts people's decision in adopting a more sustainable behavior or investing in energy efficient implementations. Furthermore, social pressure and social identity appears to be of importance for people to participate in a collective energy initiative. If insights in these psychological aspects can be obtained, it becomes more clear what motivates people to participate in a prosumer community and to what extent are they willing to adopt an energy curtailment of investment behavior. Finally, individual behavior can also be influenced by contextual forces, such as government regulations or public policies. Therefore, the government can play a major role in encouraging people to use less energy by for example financial incentives.

In line with the objective of this research, a prosumer community can be seen as an innovative concept, which needs to be adopted to achieve energy-neutral neighborhoods and cities. The willingness of people to adopt this concept will be investigated in the next chapters.

5 RESEARCH APPROACH

In this chapter, the research approach is explained for executing a stated choice experiment. The aim of this research approach is to provide information on why this method is selected and how it is set-up. Furthermore, it is explained how the questionnaire is structured and how it is distributed. Finally, the multinomial logit model and latent class model are described to provide background information about the statistical models.

5.1 INTRODUCTION

In the current research, the aim is to gain insight in the decisive motivational factors of Dutch citizens to participate in a prosumer community. To find out which motivational factors are decisive in people decision, people's preferences need to be examined. For this, decision-making can be considered by presenting choices among different alternatives to individuals. Due to the complexity of this objective, it is of importance to find the right research approach that will result in a valuable outcome. According to Kemperman (2000), a choice experiment approach is a well-established multivariate technique for measuring individuals preference and choice behavior for new, not yet existing alternatives.

To estimate people's preferences, there are two broad approaches: revealed preferences and stated preferences. According to Hensher et al. (2005) stated preference data represents choice made or stated given hypothetical situations, in which people state their choice in a given circumstance. On the other hand, revealed preference data represents data collected on choices that are made in an actual market. The collection of RP data represents the collection of data on real life choices. Because the concept of a prosumer community is new and barely applied, the context of this research is a hypothetical scenario. According to Hensher et al. (2005), a hypothetical situation may lead to situations in which personal constraints are not considered as constraints at the time of choice. To overcome these constraints, it is essential that the choice experiment is as realistic as possible with use of actual numbers or applied techniques. For the execution of the stated choice approach, various individuals will be invited to participate into a choice experiment in which they will have to choose between a specific set of hypothetical scenarios.

To compose a stated choice experiment, the theory of Hensher et al. (2005) is considered in this thesis. This book focusses more on the practical aspect of an experimental design by concentrating on the subjects that matter related to the choice modeling. An experimental design is the foundation for any stated choice experiment and can be defined as "the observation of the effect upon one variable, a response variable, given the manipulation of the levels of one or more other occurred by the design" (Hensher et al., 2005, p. 100). The manipulation can be termed as attributes which can be combined with each unique levels in treatment combinations. These treatment combinations describe the profile of the alternative within the choice set.

In Figure 9, the process of Hensher et al. (2005) to generate stated preference experiments is summarized in an experimental design process scheme, starting with the refinement of the problem. In this stage, the research problem should be clarified and the objectives of the research must be well-defined. The aim of this research approach is to answer SQ4: To what extent are local citizens willing to change their behavior to participate in a prosumer community? And to what extent is their willingness influenced by decisive motivational factors? In so far, the theoretical background (Chapter 5) has provided an answer to the decisive motivational factors on individual energy behavior (research question 3). The objective is to find out if the findings of the literature review influence people's behavior in a new context.

When the problem is well understood by the researcher, the stimuli must be refined and identified to be used in the experiment. In this stage, the various alternatives, attributes and attribute levels need to be identified. According to Hensher et al. (2005), the list of alternatives should be "universal" but "finite", which means that all alternatives are presented to the respondents that falls within the context of the study. However, to avoid too many alternatives, the alternatives should be culled from the list in order to reach a manageable size. way to reduce the alternatives is to exclude "insignificant" alternatives. In making this decision, the researcher is placing more weight on practical, as opposed to theoretical, considerations.

When the alternatives to be studied are identified, the next step in the stimuli refinement is to define the attributes and attribute levels. In this stage, the relevant attributes and attribute levels are assigned to each alternative. This is a carefully process to prevent "inter-attribute correlation", which refers to the cognitive perceptions decision makers bind to the attribute descriptions provided. Therefore, the attributes should be independently estimated in the generated experimental design. The next step in this stage is to derive the attribute levels. According to Hensher et al. (2005, p. 107), the attribute levels are defined as "the levels assigned to an attribute as part of the experimental design process". This is not an easy task, which can be attributed to several important decisions to be made by the researcher. The first concern is to decide how many attribute levels need to be assigned to each attribute, noting that not all attributes have the same attribute levels. Furthermore, the attribute levels should compromise the extreme ranges of the attribute. Therefore, the researcher should identify the attribute level extremes by examining the experiences related to that attribute of the decision makers being studied.

Once the stimuli refinement is finished, considerations regarding the experimental design need to be examined. In this stage, the type of design is chosen and the model is specified by the researcher and takes the decision whether a full factorial design or a fractional factorial design is used and whether the numbers of levels of the attributes should be reduced or not. According to Hensher et al. (2005), the main difference between these designs is that a full factorial design tests all possible treatment combinations and a fraction factorial design only tests a subset of the treatment combinations. Because a full factorial design is too comprehensive, a fraction factorial design is commonly applied.

The fourth and fifth stage occur simultaneously and refer to the generation of the experimental design. In these stages, the design strategy is adopted and the attribute levels are coded by allocating the attributes to the design columns. For the coding structure, the attribute levels can be dummy coded or effect coded. The difference between these coding structures is that the utility in the last level of the coded variable is -1 instead of 0. For this research, it is decided to assign the effect coding structure to the experimental design. By using dummy coding, the data is perfectly confounded at the last level of the variable with the grand mean (Hensher et al., 2005). The main advantage of using effect coding at the last level is that the utility is not perfectly confounded and have a unique value instead of 0.

In stage 6, the choice sets are generated by different treatment combinations of attribute levels. Hensher et al. (2005, p. 166) defines a choice set as "a mechanism of conveying information to decision makers about the alternatives, attributes and attribute levels that exist within the hypothetical scenarios of a study". Basically, in the previous stage, the various alternatives are already coded. In the generation of choice sets, it is essential that each attribute level is unique within the stated choice experiment. It is up to the researcher to replace the design codes by the attribute levels, because there is no standard approach.

Subsequently, in stage 7, the choice sets are randomized in order to present a random selection to the respondents. The randomization can be executed in Microsoft Excel, by using the function "=ASELECT()". When all stages are completed, the researcher can start with constructing the survey. In this survey, the researchers questions respondents to express their preference for each choice set. The purpose of the survey is to clarify the alternatives, attributes and attribute levels to the respondents so that they completely understand the choice experiment. Once the survey is completed, it can be distributed among the target group. The experimental design process of Hensher et al. (2005) is a suitable guideline for the researcher by presenting the sequence of stages in order to result in a valuable outcome.

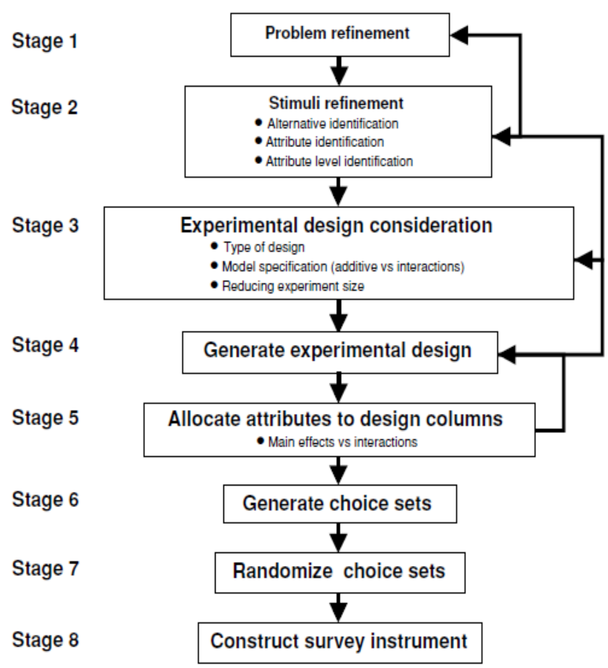

Figure 9 Experimental design process (Hensher et al., 2005)

5.2 STIMULI REFINEMENT

5.2.1 Refining the list of alternatives

Because the problem refinement is already extensively discussed in the previous chapters, the process starts with the stimuli refinement. In this stage the list of alternatives, attributes and attribute levels need to be identified, beginning with providing the list of alternatives for this research. In this thesis, two alternatives are considered that are related to the main decisive motivation of people to invest, namely: financial consequences. As discussed in chapter 4: Financial Optimizations, the investment can be realized in two ways: own initiative or outsourcing by an Energy Service Company. In the case of realizing the investment by own initiative, people realize the initial investment by their own, but this lead to substantial financial benefits each year. On the other hand, people can also decide to outsource the investment by an Energy Service Company and gain small financial benefits each year. However, in the second alternative, people conclude a contract for multiple years and after this period, the energy efficient implementations are theirs including the financial benefits. In the stated choice experiment design, these alternatives are presented to the respondents.

5.2.2 Refining the list of attributes and attribute levels

Having identified the alternatives for this research, the attributes including the attributes levels need to be determined for those alternatives. In this stage of the process, it is of importance that each alternative may incorporate a mix of common as well as different attributes. The objective is to identify local citizens' attitude, satisfaction, motivation and self-efficacy towards participating in a prosumer community. Therefore, insight in energy behavior characteristics are essential by defining the attributes for this research. These insight in combination with socio-demographic characteristics are interesting to determine what type of local citizens are suitable to live in a collective energy initiative as a prosumer community. In this thesis, four attributes are defined according to the literature review and interviews with experts of Sweco Nederland. The selection of the four attributes are included in the stated choice experiment based on the most important features. For the experimental design, it is decided to apply three levels per attribute. This is efficient to estimate the model. To understand the listed assumptions in Table 15, all attributes and their levels are explained in this section.

Financial consequence

According to the many researchers (Das et al., 2018; Frederiks et al., 2015; Wang et al., 2011), the immediate high initial cost for people to invest in energy-efficient house improvements may constrain people's decisions. Therefore, the researchers recommend to encourage the adoption of energy efficient implementations by offering monetary incentives. The financial consequence attribute includes a subdivision of type of implementations to participate (Solar panels, BTES system, and In-home batteries), the investment costs, the financial benefits per year and payback period / contract period. There is a difference in levels between the alternative own initiative and outsourcing. By looking at the financial consequences for both alternatives, there is a large difference. The main difference can be contributed to the fact that people can invest or outsource the investment in energy efficient implementations to participate in a prosumer community. However, it is their decision to what extent they prefer substantial financial benefits each year and their level of dependency to an extern company. For the outsourcing attribute levels, it is assumed that the contract is one year longer than the payback time. In addition, the financial savings for the alternative outsourcing are based on an assumption and provide a financial incentive. In conclusion, the objective of this attribute is to measure people's consideration to what extent they prefer to invest and gain financial benefits each year. This attribute is supported in the stated choice experiment by an additional question in which respondents are questioned if their decision is based on the implementation, financial savings or payback time / contract duration.

Community participation
The amount of local citizens that are involved in the prosumer community project can have an effect on other citizens in the neighborhood. According to Lin (2015) and Yue et al. (2013) perceived social pressure and peer education can modify people's energy behavior even without receiving an economic reward. The objective of this attribute is to consider whether people are influenced when a large or low share of citizens in the neighborhood participate in a prosumer community project. Therefore, three scenarios are proposed to the respondents. The scenarios are based on three levels, which are 25, 50 and 75 percent participation of neighbors in the neighborhood.

Control of appliances
In a prosumer community, electricity is generated decentral and is dependent on the weather conditions. Because a balanced system is required to reduce the import of electricity, a demand side management software is installed to manage the production and consumption of energy. In this system, energy consumption patterns can be changed in which large consuming appliances (such as dishwasher, washing machine and dryer) are used during the energy peak moments (between 11 am and 3 pm). The objective of this attribute is to gain insight in to what extend people prefer flexibility over financial savings or vice versa. There are three scenarios presented to the respondents that differ in flexibility. In the first level, people control their appliances by their own preference, which gives a lot of flexibility. However, financial savings are still dependent on people's energy consumption pattern change. In the second level, the appliances are semi-automatic controlled. Semi-automatic means in the context of this research that appliances can be programmed to turn on when the production of electricity is highest. People have the option to indicate an end time for when the appliance must be finished. This level leads to less flexibility for users, but they gain some financial benefits. In the final level, appliances are automatic controlled in which they are programmed to turn on when the production of electricity is the highest. In contrast to the second level, users cannot specify an end time and are dependent on the energy production. This leads to a limited flexibility, but people gain larger financial benefits. In conclusion, the aim of the three levels in this attribute is to measure people's preference of changing their energy lifestyle in order to gain a balanced system.

Organizational participation
The collaboration of local citizens in a prosumer community project is also dependent on the level of people prefer acting as a community and take an organizational role. The realization of a prosumer community is especially in the beginning dependent on people's initiative, effort and financial support. The objective of examining this attribute is to gain insight in the organizational role people prefer at the community level based on socio-demographic characteristics. According to Koirala (2017), there are three levels of organizational responsibility, starting with an active role in which people are willing to participate with substantial responsibility of steering the prosumer community project, such as member of the board. In the second level, people are willing to participate with a minor responsibility, such as attending member meeting. In the last level, people are willing to participate, but without organizational responsibility. These levels are presented to the respondents and provide a full overview of the different organizational roles.

Table 15 Attributes

Attribute	Alternative 1: Own initiative	Alternative 2: Outsourcing
Financial consequence	Solar panels € 4.500 investment € 800 decrease annual energy costs 6 years payback period Solar panels and BTES system € 18.500 investment € 1.200 decrease annual energy costs 13 years payback period Solar panels, BTES system, battery € 24.500 investment € 1.350 decrease annual energy costs 19 years payback period	Solar panels Investment by ESCO € 100 decrease annual energy costs 7 years contract Solar panels and BTES system Investment by ESCO € 200 decrease annual energy costs 14 years contract Solar panels, BTES system, battery Investment by ESCO € 250 decrease annual energy costs 20 years contract
Community involvement	25 percent participation 50 percent participation 75 percent participation	25 percent participation 50 percent participation 75 percent participation
Control of appliances	Own control Semi-Automatic controlled Automatic controlled	Own control Semi-Automatic controlled Automatic controlled
Organizational participation	Active role (4 hours / month) Minor participation (2 hours / month) Passive role (0-1 hours / month)	Active role (4 hours / month) Minor participation (2 hours / month) Passive role (0-1 hours / month)

5.3 EXPERIMENTAL DESIGN CONSIDERATIONS

When the alternatives, attributes and attribute levels are determined, an appropriate experimental design must be selected. In this experimental design, the total number of attributes that is included in the questionnaire is 8 (4 attributes for 2 alternatives) and each attribute involves 3 levels. This means that a 3^8th design is needed. The full factorial design contains 6.561 treatment combinations. This would enable the estimation of all possible main and interaction effects, but it cannot be easily handled by the respondents (Hensher et al., 2005). Therefore a fractional factorial design is preferred with 27 profiles. Each of the 27 profiles defines the attribute levels of the 'own initiative' and the 'outsourcing' alternative. The 27 profiles were equally and randomly distributed over 3 respondents. As a result, 9 profiles were presented to each respondent, which was randomly repeated for many respondents. This third alternative is defined as 'none of these' and is added to not oblige respondents to answer if they might not accept the presented alternatives. For the distribution of the choice sets, it is required to gain at least 150 completely filled in questionnaires.

In the experimental design, the attribute-levels (0,1,2) are replaced by a coding scheme in order to allow for arithmetic operations. The attribute levels can be dummy coded or effect coded. An example of effect coding is presented in Table 16. In the case of dummy coding, the third level will be coded 0 0. For this research, it is decided to use effect coding. By using dummy coding, the data is perfectly confounded at the last level of the variable with the grand mean (Hensher et al., 2005). The main advantage of using effect coding is that the utility is not perfectly confounded and has a unique value instead of 0. The 3 level variable is recoded into a 2 variables, in which the third level is the reference category. This category is not considered in the output of the analysis, but can be determined by assigning the negative sum of the two other levels. The calculation is as follows: X1c = -(X1a+X1b) in which it is required that the sum of the 3 levels is 0. The complete effect coding for the entire design can be found in Appendix III.

Table 16 Effect coding structure

Attribute:	**Level no**	**Levels**	**Coding X1a**	**Coding X1b**
Control of appliances	1	Own control	1	0
	2	Semi-Automatic controlled	0	1
	3	Automatic controlled	-1	-1

5.4 QUESTIONNAIRE DESIGN

In order to conduct the aforementioned choice experiment, a questionnaire is composed. The questionnaire is designed in the ‘Berg Enquête System’, which is provided by the Eindhoven University of Technology. This system is a well-established online tool for students of the department of Built Environment to construct a survey by their own. For this research, the survey is divided in three parts: socio-demographic characteristics questions, the choice experiment and a list of statements to gain insight in people’s environmental conscious attitude. Each of these parts have a different purpose of collecting data. Since the context of this research focusses on the Dutch situation, the questionnaire is only provided in Dutch. The questionnaire can be found Appendix II: Questionnaire.

As discussed, the questionnaire contains three main parts, starting with questions regarding the socio-demographic status of the respondents. Next to collecting this specific data, these questions are also a warm-up for the respondent before starting the choice experiment. The socio-demographic questions focuses on people’s: gender, age, education, household situation, income, neighborhood level, type of dwelling, property ownership. According to the literature provided in section 5.6.1, these are the aspects that are examined in previous studies and can provide information about the socio-demographic characteristics of respondents.

In the second part of the questionnaire, the choice experiment is conducted, starting with a context description. In this description, an introduction of the choice experiment is given and both alternatives are explained. When this is clear for the respondent, the next page shows an example of a choice set that can be expected. For the readability of the survey, first the example is presented and hereafter the attributes of the choice sets are explained. This might prevent respondents from early quitting. In this explanation, misunderstandings must be avoided by providing a detailed description of the attributes and attribute levels. Next, the respondents are invited to evaluate nine choice situations. The respondent can choose between three alternatives: own initiative, outsourcing and none of these. Each choice sets is supported by an additional question that can be found below the choice task. The aim of this question is to gain insight in the decisive financial aspects where people’s choice is based on. In addition, this question provides the possibility to tick for multiple choices. When the nine choice sets including the additional question are finished by the respondent, the choice experiment part is completed.

“Which of the aspects of financial consequences were influential in your choice?” (multiple choices are possible):
- *Investment implementations (solar panels, BTES system, in-home battery)*
- *Financial savings per year*
- *Payback/contracting period*
- *None of these”*

The third and last part of the questionnaire consist of multiple statements in which people’s environmental attitude can be measured. These statements are considered to find out if people who identify themselves as having an environmental attitude have a different choice behavior than people who identify themselves as having a less environmental attitude. The statements are based on previous literature and are presented to the respondents as a five-point Likert scale. The reason for placing these statements on the last page of the survey is because fatigue in an earlier stage should be avoided. Therefore, these questions, which are easily to respond, are questioned at the end. The following statements are presented to the respondents.

- *I am worried about global warming.*

This statement is based on the environmental awareness of people, which is frequently reported by different researchers. According to Wang et al. (2011), attitude refers to the degree of people’s pro-environmental awareness of performing sustainable behavior. This behavior contributes to energy curtailment or/and energy investment behavior of people. Barreto et al. (2014) underlined this statement and added that it has been shown that most people are concerned about future generations access to renewable sources, which influence their environmental awareness.

- *The majority of the population is not acting environmentally conscious.*

According to Berendsen et al. (2010), there is a gap between environmental conscious and acting environmental conscious. This gap can be contributed to the tragedy of common hypothesis, which assume that people prefer to gain economic benefits by the lowest possible costs in the choice of a behavior in a social dilemma. The statement gives insight in the behavior of respondents and their environmental awareness.

- *I am prepared to pay more for environmentally friendly implementations.*

In the literature review on individuals’ energy behavior, the financial consequence is one of the main considerations of people. However, Yue et al. (2013) states that consumers are willing to invest more in appliances with an higher energy efficiency label.

- *The government should conduct more action to tackle the climate problem.*

The edition of the citizens perspective questionnaire conducted by the Dutch government (Dekker et al., 2016) focusses on the energy transition of the Netherlands. According to the results, 55% of the Dutch citizens have almost no confident in the government related to the energy transition and the approach against the climate change problem. However, citizens expects that the government will come up with solutions, but preferably not with implementations that affects the individual.

- *I would like to be more independent of large energy providers.*

According to the citizens perspective questionnaire (Dekker et al., 2016) , 57% of the Dutch citizens have almost no confident in the large energy providers. Dutch citizens also concern the links and dependency on countries as Russia because of their gas supply. These developments lead to more initiatives (such as power peers), in which people generate their own energy and become more independent of large energy providers.

- *I am willing to adopt a more environmental friendly lifestyle.*

According to Han et al. (2013) and Barreto et al. (2014), people can adopt a more curtailment behavior by for example reduce the usage of existing equipment's or appliances by behavior changes, such as shortening shower duration, switching of light, lowering thermostat setting, etc. Such changes in energy consumption behavior requires alteration of lifestyle in which people mostly choose to decrease their comfort. Therefore, people should be more willing to modify their energy behavior and lifestyle to address environmental concerns.

- *I would like to be seen with solar panels on my house.*

Social identity is a motivational factor for people to apply energy efficient implications. This statement is underlined by the research of Barreto et al. (2014), which states that people are more willing to modify their behavior when the impact becomes visible to their social network. This expression is in line with social influences, such as peer pressure, public accountability and competition.

- *I am willing to participate in a prosumer community.*

When the respondents have completely filled in the questionnaire, the final question focusses on their willingness to participate in a prosumer community. It can be expected that respondents have a plenary idea of what a prosumer community includes. By questioning this statement, all important motivations can be considered and respondents can give their concluding answer.

When the first version of the questionnaire was completed, it was tested among 10 respondents. The questionnaire was adjusted according to their feedback. The questionnaire will be distributed among consumers who own or rent a dwelling by means of a link to the online survey system (the BERG system, developed at TU/e). The goal is to collect data from at least 150 respondents, preferably representatively distributed across the main socio-demographic characteristics (such as: gender, age, income, education, etc.). This is of importance for the elaboration of the results and to formulate reliable conclusions.

5.5 MULTINOMIAL LOGIT MODEL (MNL)

When the choice data is obtained by the distribution of the questionnaire, it is subsequently analyzed by using a multinomial logit model (MNL). According to Davis et al. (1979), the multinomial logit model is "an appropriate multi-attribute analysis for measuring the choice behavior of individuals". The model is able to predict individual decision maker's overall preference of a choice alternative and can overcome models that contains no complex relationships. In addition, the model can predict an individual utility for an alternative by two components: based on expressed attitude towards that alternative and an unobserved random component. The utility factor of the different attributes can be calculated by the following equation (Davis et al., 1979).

$$U_i = V_i + \varepsilon_i \quad (6.1)$$

Where, U_i is the utility of the alternative to individual *i*, V_i is the deterministic component, and ε_i is the random component, which is assumed to be independent and identically distributed across all individuals *i*. According to Hensher et al. (2005), the functional relationship between the utility associated with an alternative and the variables can be assumed as:

$$V_i = \beta_{0i} + \beta_{1i} f(X_{1i}) + \beta_{2i} f(X_{2i}) + \beta_{3i} f(X_{3i}) + \cdots + \beta_{ki} f(X_{ki}) \quad (6.2)$$

In which β_{ki} is the weight (or parameter) of attribute X_k and alternative *i* and β_{0i} represents the alternative-specific constant, which represents on average the role of all the unobserved sources of utility and is not associated to the observed and measured attributes.

To estimate the probability of an individual choosing alternative i out of the set of J alternatives, equation (6.3) can be used. This equation states that the probability of an alternative is equal to the ratio of the exponential of the utility for alternative i to the sum of the exponentials of the utilities for all J alternatives (Hensher et al., 2005).

$$\mathrm{P}_i = \frac{\exp V_i}{\sum_{j=1}^{J} \exp V_j} \ ; \quad j = 1, \dots, i, \dots, J \quad (6.3)$$

To estimate the most likely value of each parameter in equation 6.2, the log-likelihood function can be used:

$$LL = \sum_{n=1}^{N} \sum_{s=1}^{S} \sum_{j=1}^{J} y_{njs} \ln(P_{njs}) \quad (6.4)$$

where y_{njs} is 1 if alternative *j* was chosen by respondent n in choice situation *s* and 0 otherwise, P_{njs} represents the probability that respondent , and $\ln$ is the natural logarithm. Maximizing (6.4) yields the maximum likelihood estimator, $\hat{\beta}$, of the specified choice model given a particular set of choice data. The function is retrieved from (Hensher et al., 2005).

When the log-likelihood function is determined for the estimated parameters and the null model, the goodness-of-fit can be calculated. To determine the goodness of fit of the estimated model, McFadden's Rho-Square can be used for fitting the overall model. McFadden suggest p^2 values of between 0.2 and 0.4 should represent a very good fit of the model (D. Lee, 2013).

$$p^2 = 1.0 - [\ LL(\beta) \ / \ LL(0)\ ] \quad (6.5)$$

In this formula, the $LL(\beta)$ is the log-likelihood function using the estimated parameters and $LL(0)$ is the log-likelihood function using the null-model (all $\beta's$ being equal to 0) (Hensher et al., 2005).

5.6 LATENT CLASS MODEL (LCM)

A latent class model is used in this research to estimate the parameters for a given number of classes (or clusters) of respondents which are determined by the model as well. By executing a latent class model analysis, clusters of individuals are obtained, which have a similar choice behavior. For each cluster, a set of parameters is estimated. The objective of this study is to investigate whether the respondents belonging to one cluster also share similar socio-demographic characteristics or have the same environmental conscious attitude.

To identify the optimal number of classes for the latent class model, the Bayesian Information Criterion (BIC) is often used (Feng, Arentze & Timmermans., 2010). This calculation is based on the number of classes that are expected to be determined. This formula can be expressed as:

$$BIC = -2LL + 2K \tag{6.6}$$

In this formula, LL is the log likelihood and K is the number of parameters in the model. As a rule of thumb, the lowest BIC value contributes to the most reliable model. Besides the BIC, the total fit of the model can also be determined by the McFadden's rho square.

5.7 CONCLUSION

In this chapter, the research approach is explained for executing a stated choice experiment. The aim of executing a stated choice experiment is to measure the preferences and choice behavior of citizens to participate in a prosumer community. The aim of the research approach is to answer SQ4: To what extent are local citizens willing to change their behavior to participate in a prosumer community? And to what extent is their willingness influenced by decisive motivational factors? For composing a stated choice experiment, the theory of Hensher et al. (2005) is considered, starting with the stimuli refinement. In the stimuli refinement, the alternatives, attributes and attribute levels are determined. In this research, two alternatives are presented to the respondents: own initiative and outsourcing. Per alternative, four attributes are questioned based on the literature: financial consequences, community involvement, control of appliances and organizational participation. To these attributes, three levels are assigned. A fractional factorial design is used with 27 profiles, in which 9 profiles are presented to each respondent. One profiles defines both alternatives. For the experimental design considerations, it is decided to use effect coding for the attribute levels. The 3 level variable is recoded into 2 variables; the third level is the reference category. When the experimental design and choice sets were generated, 9 randomly selected choice sets were presented to each respondent. Furthermore, the questionnaire was designed in the BERG Questionnaire system and included three main parts of different questions. In the first section, the socio-demographic characteristics were questioned to gain insight in the socio-demographic status of the respondents. In the second part, the choice experiment is conducted. The choice experiment part included a context description and the invitation to choose one alternative from each of to the 9 choice sets. In the last part of the questionnaire, environmental statements were questioned to the respondents to gain insight in people's environmental conscious attitude. Finally, the multinomial logit model and the latent class model were explained in this chapter. The multinomial logit model is executed in the analysis to assess individual decision maker's overall preference of choice alternatives. Furthermore, the latent class model will be used to find homogeneous clusters of respondents.

6 RESULTS

In this chapter, the output of the questionnaire is analyzed according to different statistical approaches. First, the sample is described and compared to the Dutch population. Next, the cross tab results between the socio-demographic characteristics and the environmental statements are explained. Subsequently, the Multinomial Logit Model is executed to analyze the choice behavior data based on the stated choice experiment. Finally, the Latent Class Model analysis is executed to discover classes based on similar choice behavior.

6.1 DATA COLLECTION

The data collection took place between May 2nd and May 16th 2018 by distributing the online questionnaire at two channels. First, in collaboration with the communication department of Sweco, an article about this research was prepared and shared at the official Sweco website. Hereafter, the communication department shared this article two times in two weeks at the Sweco LinkedIn Page (9.775 followers), the Sweco Facebook Page (1.600 followers) and via a mail to the department of Energy. In the second channel, data were obtained by my own network using a call on Facebook, personally questioning LinkedIn contacts, and help from family and friends to share the questionnaire to whom they know. After two weeks of data collection, the questionnaire was opened 1189 times. From the 1189, 201 respondents filled in the questionnaire including the choice experiment. Finally, 184 respondents finished the questionnaire by completing all questions.

6.2 SAMPLE DESCRIPTION

In the first part of the questionnaire, respondents were questioned regarding their personal characteristics. These social-demographic characteristics help to provide a description of the data sample retrieved. In Table 17 and Table 18, the social-demographic characteristics are compared to the corresponding distribution of the Dutch population. To test the representativeness, the chi-square test is performed for each socio-demographic characteristic. In this chi-square test, the specific characteristic is tested to the expected values based on the percentage of The Netherlands for each level. If the result of the chi-square test is significant ($p < 0.05$), then the sample is not representative on that characteristic. The data concerning the Dutch population is mainly retrieved from Statistics Netherlands. The overall descriptive analysis can be found in Appendix IV: Descriptive analysis. Furthermore, the chi-square tables to determine the representativeness are presented in Appendix V: Chi-square representativeness sample.

Table 17 Frequencies questionnaire (1)

Characteristic	Level	Percent Questionnaire	Percent The Netherlands	Observed N	Expected N	Residual
Gender	Male	59.2%	49.6%	109	90	19
(CBS, 2018)	Female	40.8%	51.4%	75	94	-19
Chi-Square: 7.861						
Chi-Square sig: .006						
Age	21 to 30 years	32.6%	18.1%	60	33	27
(CBS, 2018)	31 to 50 years	39.1%	36.5%	72	67	5
Chi-Square: 33.507	51 to 75 years	28.3%	45.3%	52	83	-31
Chi-Square sig: .000						
Education (Ministry of Education, Culture	Secondary vocational education	26.6%	66.3%	63	122	-59
and Science , 2017) **Chi-Square: 85.322**	Higher professional education	47.3%	21.2%	73	39	34
Chi-Square sig: .000	Scientific education	26.1%	12.5%	48	23	25
Income	0 to 25000 euro	19.0%	41,7%	35	77	-42
(CBS, 2014)	25001 to 45000 euro	50.0%	36,2%	92	67	25
Chi-Square: 38.936	>45000 euro	31.0%	22,1 %	57	41	16
Chi-Square sig: .000						
	Total	**100.0%**	**100.0%**	**184**		

As can be seen in the first row of Table 17, the collected sample includes more males than females. When comparing this result with the percentage of the Dutch population, it can be noticed that the sample regarding gender is representative based on the chi-square test with a significance value of .006. In Figure 10, the distribution of the age frequencies of the samples is presented. According to this distribution, three categories are created between 21 and 75 year. As can be noticed, the characteristic age is not representative to the Dutch population, especially by considering the deviation of the first and the last category. As expected, most respondents of the sample are high educated. This can be attributed to the distribution of the questionnaire in which a large quantity of respondents is obtained by the Sweco LinkedIn call. Due to the questionnaire distribution, the characteristic education is not representative to the Dutch population based on the chi-square test. Finally, the characteristic income deviates from the distribution of the Netherlands. As a result, this characteristic is not representative to the Dutch population based on the chi-square test.

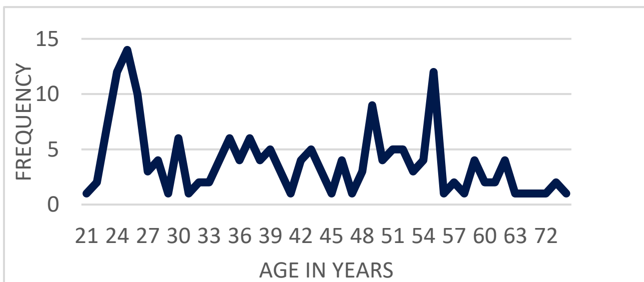

Figure 10 Frequency age

Table 18 Frequencies questionnaire (2)

Characteristic	Level	Percent Questionnaire	Percent The Netherlands	Observed N	Expected N	Residual
Household composition	1-person household	10.3%	38.0%	19	70	-51
(CBS, 2017)	2-person household	44.0%	32.6%	81	60	21
Chi-Square: 60.977	3-person household	18.5%	11.9%	34	22	12
Chi-Square sig: .000	≥4-person household	27.2%	17.5%	50	32	18
Children	No children	58.2%	65.9%	107	123	-16
(CBS, 2016)	Children	41.8%	33.1%	77	62	15
Chi-Square: 5.852						
Chi-Square sig: .016						
Dwelling type	Detached house	10.9%	23.0%	20	38	-18
(CBS, 2016)	Semidetached house	35.9%	19.6%	66	59	7
Chi-Square: 10.548	Terraced house	36.4%	42.5%	67	59	8
Chi-Square sig: .014	Apartment / Gallery home	16.8%	15.0%	31	28	3
Property ownership	Property owner	73.4%	56.9%	135	105	30
(CBS, 2017)	Property renter	26.6%	43.2%	49	79	-30
Chi-Square: 20.116						
Chi-Square sig: .000						
	Total	**100.0%**	**100.0%**	**184**		

In Table 18, the frequencies concerning household composition, presence of children in the household, dwelling type and property ownership are presented. As can be seen, the sample includes more ≥2-persons households and less 1-person households compared to the Dutch population. Based on the results of the chi-square test, the characteristic household composition is not representative to the Dutch population. Secondly, in the characteristic presence of children, there is a slight deviation between the sample and the Dutch population. Still, this characteristic is not representative to the Dutch population. In the third row, the four levels of the characteristic type of dwelling are presented. As can be noticed from the frequencies for dwelling type, most of the repondents lived in a semidetached house or in a terraced house. However, this characteristic is not representative to the Dutch population, which can be caused by the negative deviation of the level detached house. Furthermore, most respondents in the distributed sample own their property instead of renting their property. Due to this deviation, the chi-square indicates that this characteristic is not representative to the Dutch population. Finally, the respondent distribution in the Netherlands can be seen in Figure 11. As shown, the questionnaire is not equally distributed over the different provinces, which can be attributed to the data collection. In conclusion, only the characteristic gender is representative to the Dutch population. The remaining characteristics cannot considered to be representative.

Figure 11 Distribution questionnaire over The Netherlands

6.3 ANALYSIS OF ENVIRONMENTAL STATEMENTS

In this section, the results of the eight statements that have been questioned at the end of the questionnaire, are analyzed. To gain a more complete overview of the results, the answers of the statements are combined with the socio-demographic characteristics of the respondents. The socio-demographic characteristics are: gender, age, education, income and presence of children. The 5-point Likert-scale has been reduced to a 3-point Likert-scale because the frequency of strongly agree and strongly disagree was too low. Furthermore, the cross tables are substantiated by the Pearson Chi-square test. The Crosstabs and test results can be found in Appendix VI: Crosstabs statements.

6.3.1 Statement 1: I am worried about global warming

In the first statement, respondents were questioned if they are worried about global warming. As can be seen in Figure 12, 76.6% agreed on this statement, 15.8% was neutral and 7.6% of the respondents disagreed. According to the chi-square results (Appendix VI: Crosstabs statements), for none of the characteristics significant different from the overall distribution were found, which means that there are no differences. Based on the overall results, it can be concluded that on average the respondents are environmental conscious.

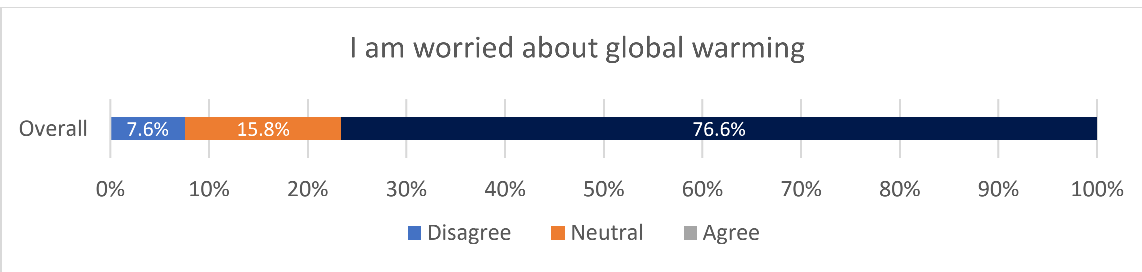

Figure 12 Statement 1: I am worried about global warming

6.3.2 Statement 2: The majority of the population is not acting environmental conscious

From the results of Appendix VI: Crosstabs on statement 2 can be concluded that 82.1% agreed, 13.0% of the respondents were neutral and a slight percentage of 4.9% disagreed. According to the chi-square table, only age is significant. In Figure 13, the levels of the characteristic age are presented. As can be noticed, people between 21 years and 50 years agreed more than the overall distribution. However, people above 50 years agreed less than the average with 69.2%. All in all, it can be concluded that people agree with the statement that the majority of the population is not acting environmental consciously.

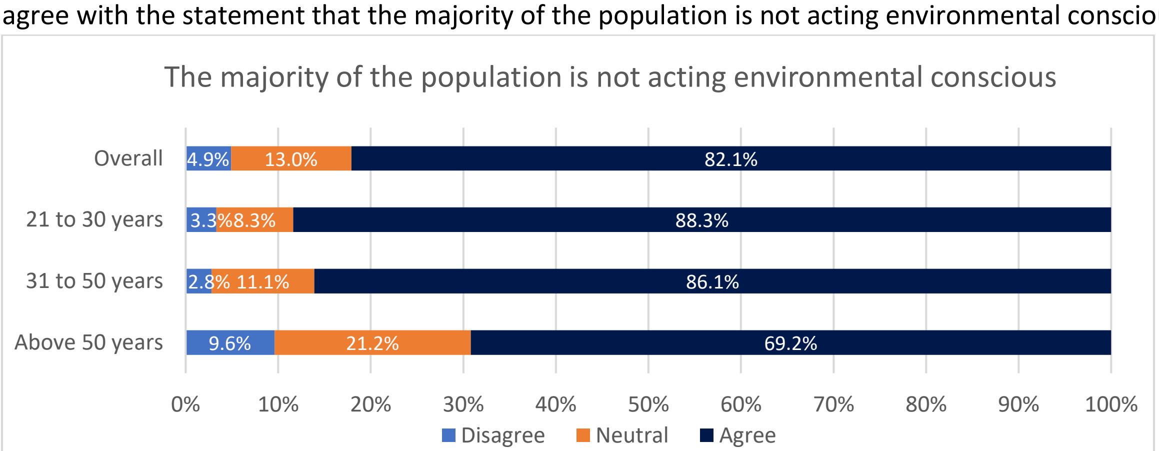

Figure 13 Statement 2: The majority of the population is not acting environmental conscious

6.3.3 Statement 3: I am prepared to pay more for environmental friendly measures

In the third statement, respondents were questioned if they are prepared to pay more for environmental friendly measures. On average, 52.2% of the respondents agreed, 32.6% had a neutral opinion and 15.2% disagreed (Appendix VI: Crosstabs statements). According to the chi-square results, the characteristics age, education and income significantly affect the scores. In Figure 14, the levels of the characteristics age, education and income are presented. First, looking at the characteristic age, mainly people from 31 to 50 years agreed more than the average with 65.3%. This is in line with the results of Yue et al. (2013), who states that people between 31 and 45 years old are more willing to adopt an investment behavior. This is caused by their ability to pay for energy-efficient implementations and awareness of the advantages. Secondly, as can be seen in the levels of the characteristic education, people with a higher education are more prepared to pay for environmental friendly measures. These results are in line with the research of Sardianou and Genoudi (2013), who conclude that higher educated individuals are more willing to invest in energy efficient implementations than lower educated individuals. Finally, there is a significant difference in the characteristic income. According to the results, people with a higher income are more willing to invest in energy efficient implementations than people with a lower income. These results are in line with the research of Yue et al. (2013), who states that people who have a low income are more willing to adopt energy curtailment behavior, while people with a high income are more willing to adopt energy investment behavior.

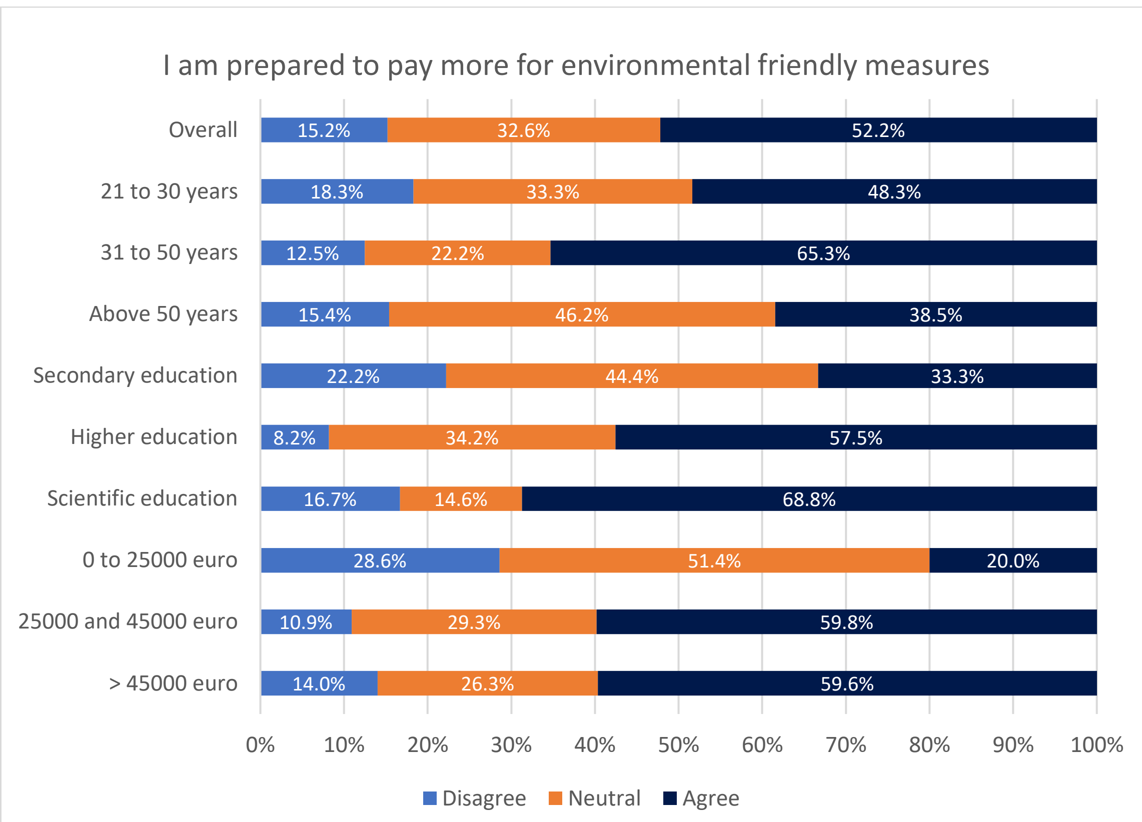

Figure 14 Statement 3: I am prepared to pay more for environmental friendly measures

6.3.4 Statement 4: The government should take more action against the climate problem

In statement 4, respondents were questioned if they think that the Dutch government should take more action against the climate problem. In total, 84.8% agreed on this statement, 12.5% were neutral and 2.7% disagreed (Figure 15). These results are in line with the citizens perspective questionnaire (Dekker et al., 2016), in which 55.0% had almost no confident in the Dutch government towards the energy transition. According to the chi square table (Appendix VI: Crosstabs statements), none of the characteristics are significant different from the overall distribution. Based on the overall results, it can be stated that people strongly agree on this statement, which indicates their dissatisfaction to the current energy transition policy.

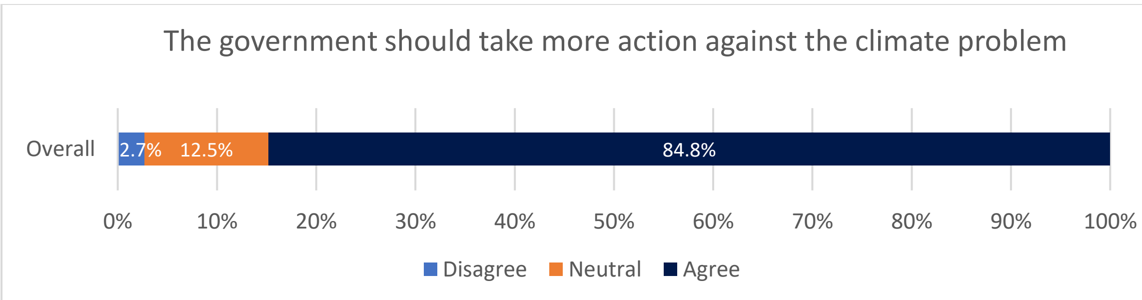

Figure 15 Statement 4: The government should take more action against the climate problem

6.3.5 Statement 5: I would like to be more independent of large energy providers

In Figure 16, the results of statement 5 are presented. As can be seen, most people would like to be more independent of large energy providers. In total, 54.9% agreed on this statement, 27.7% were neutral and 17.4% disagreed. This is in line with the results of the citizens perspective questionnaire (Dekker et al., 2016) that notifies that 57% of the Dutch citizens have almost no confident in the large energy providers. According to the chi-square table (Appendix VI: Crosstabs statements), there is a significant difference in the characteristics gender and age. As can be noticed, males prefer to be more independent from large energy providers than females. Furthermore, people from 21 to 30 years disagree more on this statement compared with the age levels 31 to 50 years and above 50 years. This result might be attributed to their short experience with energy providers.

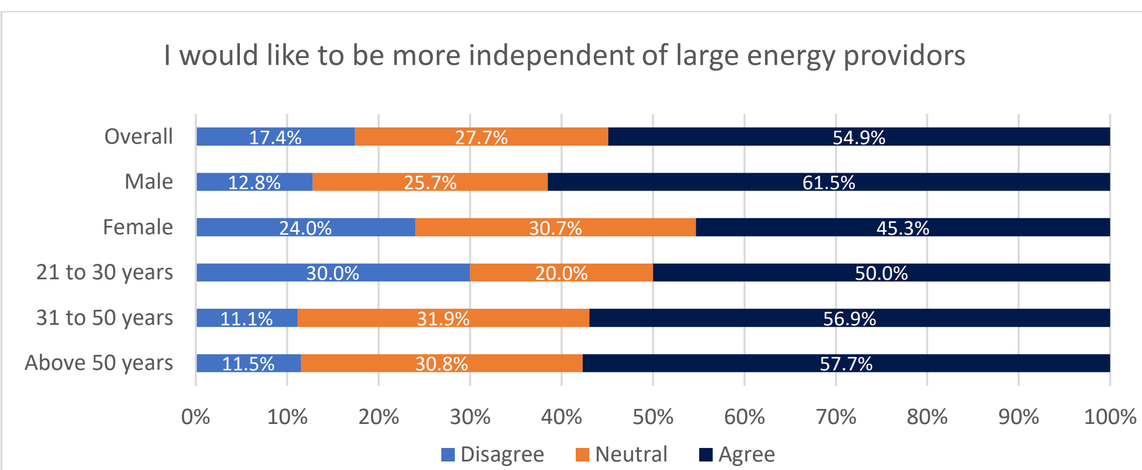

Figure 16 Statement 5: I would like to be more independent of large energy providers

6.3.6 Statement 6: I am willing to adopt a more environmental friendly lifestyle

In statement 6, the respondents were questioned if they are willing to adopt a more environmental friendly lifestyle. According to the results, 78.8% of the respondents agreed on this statement, 19.0% were neutral and slightly 2.2% disagreed (Figure 17). On average this means that the sample is very willing to adopt a more environmental friendly lifestyle. According to the chi square results (Appendix VI: Crosstabs statements), none of the characteristics how significant differences.

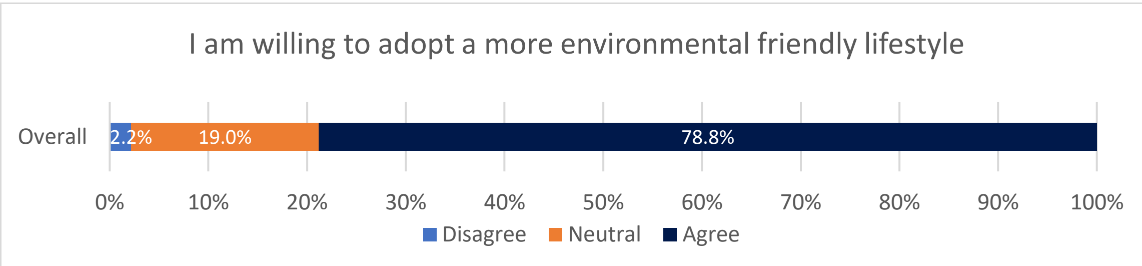

Figure 17 Statement 6: I am willing to adopt a more environmental friendly lifestyle

6.3.7 Statement 7: I would like to be seen with solar panels on my dwelling

The objective of statement 7 is to find out to what extend social identity is a motivational factor for people to modify their behavior when it becomes visible to their social network (Barreto et al., 2014). As can be seen in Figure 18, 48.9% agreed, 28.8% were neutral and 22.3% of the respondents disagreed on this statement. According to the overall results of the chi-square (Appendix VI: Crosstabs statements), there is a significant difference in the characteristics gender and education. It can be noticed from Figure 18 that males prefer to be seen with solar panels on their dwelling compared to females. Furthermore, people with a lower education agreed less than the average with 30.2%. Moreover, it can be concluded that higher educated people would more like to be seen with solar panels on their house than lower educated people.

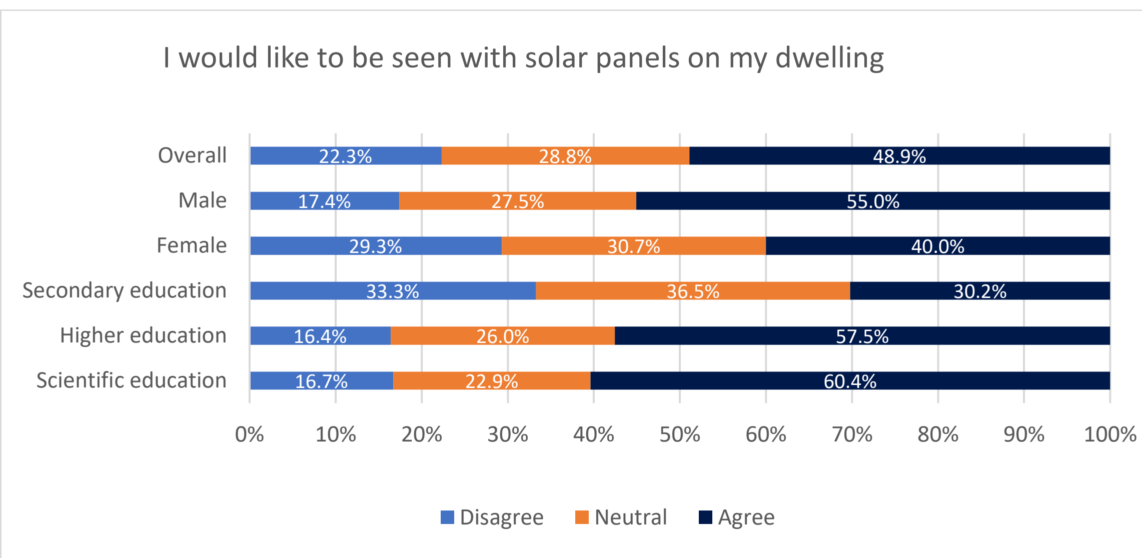

Figure 18 Statement 7: I would like to be seen with solar panels on my dwelling

6.3.8 Statement 8: I would participate in a prosumer community

The objective of statement 8 is to present a final question to gain insight to what extend people would like to participate in a prosumer community. It can be expected that respondents have a global idea of what a prosumer community includes after finalizing the questionnaire. According to the results of the overall distribution, 67.4% agreed, 22.8% had a neutral opinion and 9.8% is not willing to participate in a prosumer community (Appendix VI: Crosstabs statements). Looking at the chi-square of the characteristics, there is only a significant difference in gender and education. As can be seen in Figure 19, 76.1% of the males would participate in a prosumer community compared to 54.6% of the females. Furthermore, people who are higher educated, are more willing to participate in a prosumer community than people who are lower educated. Scientific educated people agreed by 79.2% compared to 55.5% of secondary educated people.

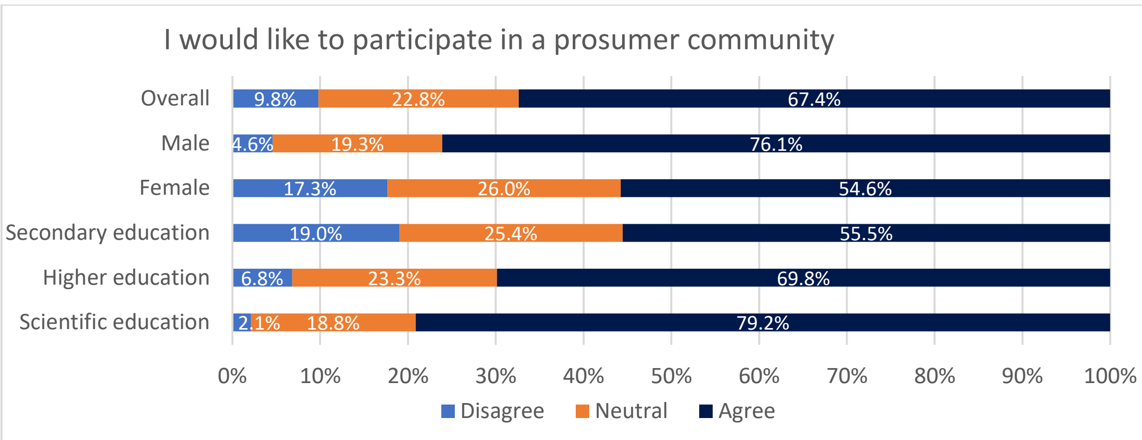

Figure 19 Statement 8: I would like to participate in a prosumer community

6.3.9 Internal consistency reliability statements

Regarding these eight different statements, the internal consistency reliability (Cronbach's alpha) has been considered. According to Gliem and Gliem (2003), a coefficient of >.80 indicates a high reliability, coefficients <.50 indicate insufficient reliability and a scale with a coefficient of >.70 is considered as reliable. In Table 19, the output of the Cronbach's Alpha coefficient is presented. As can be seen, Cronbach's Alpha is equal to 0.710, which means that 71 percent of the variability in a composite score by combining the eight statements, is considered as internal consistent reliable.

Table 19 Cronbach's Alpha coefficient

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.710	.708	8

6.4 MNL MODEL ANALYSIS

In this section, the data analysis according to the Multinomial Logit Model is explained. The results of the analysis can be found in Table 20, which are also visualized in Figures 20 and 21. In these figures, the positive and negative coefficients are presented as well as their significance levels. Looking at the goodness of fit, the MNL model has a McFadden's rho-square of 0.095 and is moderate in explaining the model. The complete results and output of the NLogit analysis can be found in Appendix VIII: Data analysis.

6.4.1 Results MNL model analysis

Before explaining the results of each attribute for both alternatives, the constant needs to be explained. As can be seen in Table 20, the constant for both the alternative own initiative as for the alternative outsourcing is close to the zero. This means that people have no specific preference. However, before adopting this conclusion, the results of the latent class model need to be analyzed.

Financial consequences

According to the results of the MNL model (Table 20), different conclusions can be drawn for the financial consequences of the three alternatives. First, in the attribute financial consequences own initiative, both levels are significant at the 1% level. As can be seen, the coefficient for the first level is positive with a value of 1.130 that contributes to the investment in solar panels. However, the coefficient of the second level is -0.317 (solar panels, BTES system) and is significant for 1%. The negative value of the sum of both coefficient represents the utility of the third level, which is -0.813 level for the level financial consequences of investing in solar panels, BTES system and in-home battery. This coefficient represents the reference category and is very likely to be significant. The coefficients in this attribute indicates that people are more willing to invest in energy efficient implementations that have no high initial investment cost, have reasonable financial savings and have a short payback period. Furthermore, it can be noticed that most people do not prefer investing in energy efficient implementations that have a high initial investment, which lead to reasonable financial savings, but have a long payback period.

Secondly, in the alternative outsourcing, the first level of the attribute financial consequence outsourcing is significant at 1% level. The positive coefficient of 0.267 shows that people prefer the financial outsourcing of solar panels, that lead to small savings in a short contract period. The second level has a slightly negative coefficient, but is not significant. Looking at the third level that represents the reference category, the coefficient is -0.243 and is very likely significant. This indicates a no preference for financial outsourcing of the energy efficient implementations of solar panels, BTES system and in-home battery, which results in moderate financial savings per year, but have a contract period of 19 years.

Community involvement

The first two levels of the attribute community involvement of 25 percent and 50 percent participation in the alternative own initiative are not significant. This means that there is no significant difference between the choice behavior of people and these attribute levels. However, the coefficient of the reference category (75 percent participation) is 0.128, in which there seems to be a slight preference for being involved by a participation of 75 percent.

Looking at the attribute community involvement of the alternative financial outsourcing, the first level (25 percent participation) has a negative coefficient of -0.199 and is significant at the 10 % level. According to this result, it can be concluded that people are less prepared to participate in a prosumer community and outsource their investment when only 25 percent of the neighborhood is being involved. Furthermore, the coefficient for 50 percent participation is not significant, which means that there is almost no difference for this attribute level. The coefficient of the third level that represents the reference category is 0.169 and is probably significant. The preference for being involved by a community participation of 75 percent corresponds with the alternative own initiative and seems to be important in people's decision.

Control of appliances
In the attribute control of appliances of the alternative own initiative, the coefficients of three levels are determined. First, the coefficient for the attribute level own control is 0.275 and is significant at the 1% level. In the second attribute level, it seems that there is a slight preference for semi-automatic control of appliances, but the coefficient of 0.104 is not significant. In the third level that represents the reference category, the negative coefficient of -0.379 is very likely significant and indicates that people do not prefer a complete automatic control of their appliances.

Corresponding results can be found in the alternative outsourcing in which the first level (own control) is significant at the 10% level. The coefficient of this attribute level is positive with 0.215 and is in line with the results of the first level of the own initiative alternative. The coefficient for second level (semi-automatic control) is 0.018 and is not significant. Furthermore, the reference category is negative with a coefficient of -0.232, which is likely to be significant. For both alternatives, it can be concluded that there is a significant preference for own control of appliances instead of automatic control.

Organizational participation
Giving the results of the MNL model, the attribute organizational participation for the alternative own initiative shows a negative coefficient of -0.246 with a significance at 1% level in the first level (active role). This means that people do not prefer to perform an active organizational role by for example being a member of the board of a prosumer community. The second level, which indicates a minor organizational role, has a slight positive coefficient of 0.172, but is not significant according to the MNL model. The coefficient of the reference category is 0.074 and is very likely to be not significant. This indicates the influence of performing a passive role in setting up a prosumer community is almost none.

Looking at the results of the alternative outsourcing, the first level (active role) has a negative coefficient of -0.196 and is significant at the 10% level. This indicates that people do not prefer to perform an active role by participating in a prosumer community. The second level contains a coefficient of 0.096 and is not significant. Finally, the reference category a positive coefficient of 0.10, in which there seems to be a slight preference for performing a passive role by participating in a prosumer community. For both alternatives, there is a pattern in which people do not prefer to be involved in organizational activities.

Table 20 Results MNL

Attribute	Coefficient MNL
Constant	
Constant 1	0.006
Constant 2	-0.061
Alternative own initiative	
Solar panels	1.130***
Solar panels and BTES system	-0.317***
Solar panels, BTES system, battery	-0.813
25 percent participation	-0.089
50 percent participation	-0.039
75 percent participation	0.128
Own control	0.275***
Semi-Automatic controlled	0.104
Automatic controlled	-0.379
Active role (4 hours / month)	-0.246***
Minor participation (2 hours / month)	0.172
Passive role (0-1 hours / month)	0.074
Alternative outsourcing	
Solar panels	0.267***
Solar panels and BTES system	-0.024
Solar panels, BTES system, battery	-0.243
25 percent participation	-0.199*
50 percent participation	0.030
75 percent participation	0.169
Own control	0.215*
Semi-Automatic controlled	0.018
Automatic controlled	-0.233
Active role (4 hours / month)	-0.196*
Minor participation (2 hours / month)	0.096
Passive role (0-1 hours / month)	0.100

1% significance level
5% significance level
10% significance level
Not significant
Unknown (reference category)

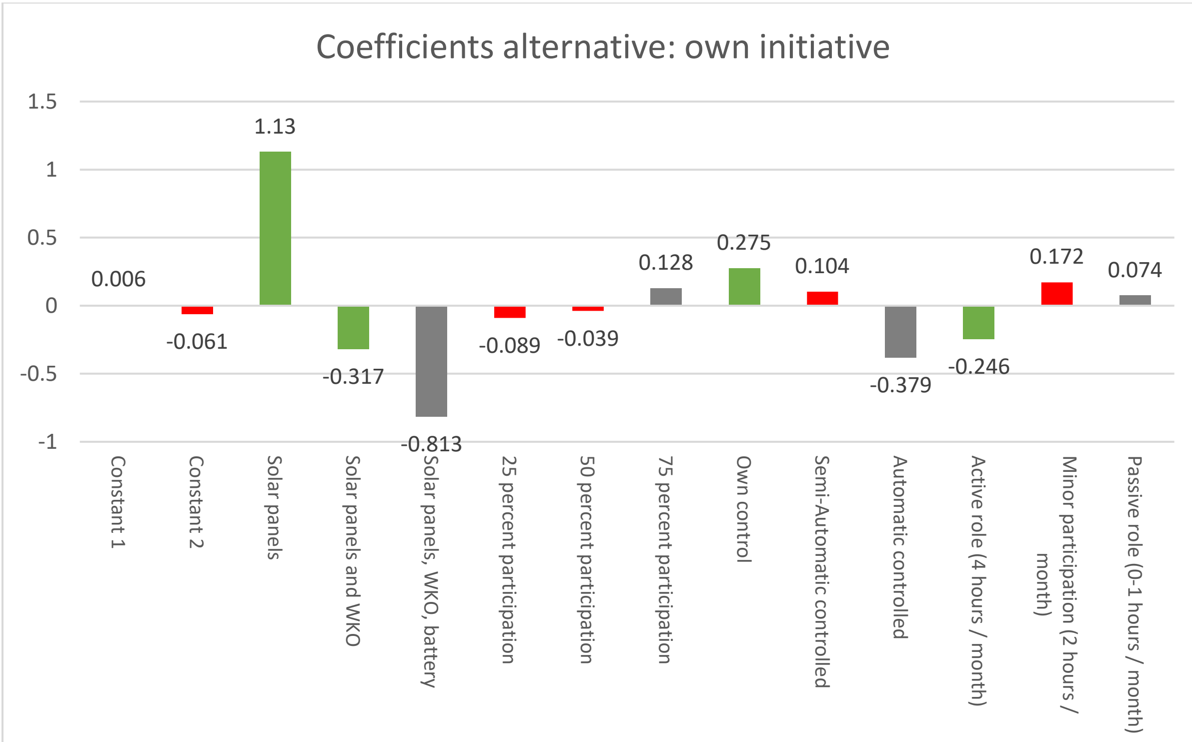

Figure 20 MNL coefficients alternative: own initiative

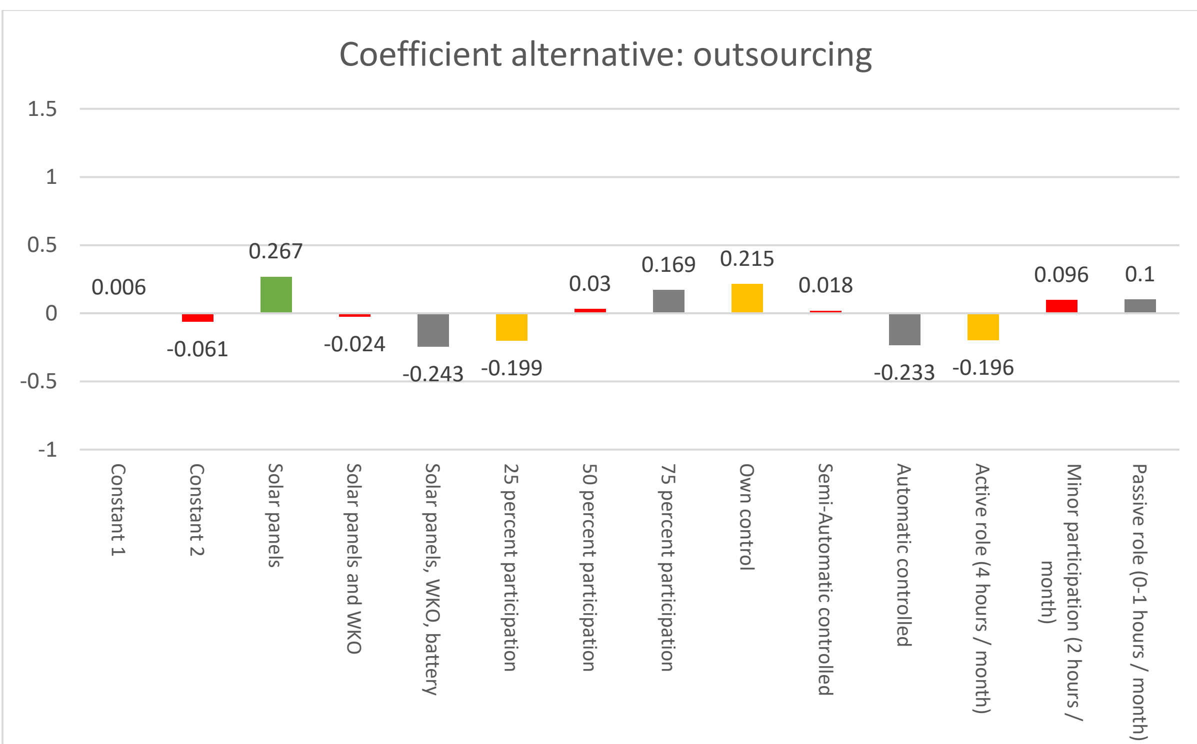

Figure 21 MNL coefficients alternative: outsourcing

6.5 LATENT CLASS MODEL ANALYSIS

The latent class model analysis is estimated to discover classes of respondents. By executing a latent class model analysis, clusters of individuals are obtained, which have a similar choice behavior. The objective of this study is to investigate whether the respondents belonging to one cluster also share similar socio-demographic characteristics or have the same environmental conscious attitude. The latent class model analysis is estimated in NLogit.

6.5.1 Results

In Table 21, the results of the latent class analysis are presented. As can be seen, two classes were generated that includes significant differences compared to the MNL model. First of all, it is worthwhile to note that the constant in the two classes deviates from the base model. In the conventional MNL model, the constants were not significant. However, the latent class model analysis shows that there are certain differences, which are both significant at the 1% level. As can be seen for class 1, the constant coefficient for the own initiative alternative is 1.876 and the constant coefficient for the outsourcing alternative is 1.763. However, in class 2, the constant coefficient are both negative, in which the constant coefficient for the own initiative alternative is -2.181 and the constant coefficient for the outsourcing alternative is -1.856. This indicates that enthusiasts and conservatives to participate in a prosumer community on both alternatives can be identified. Furthermore, the likelihood of this model is -1338.895, which is much higher than the MNL model. This results in a rho-square value of 0.264. According to the goodness-of-fit rule, the two class model performs rather well.

Results Class 1

The results of enthusiasts of the alternative own initiative are shown in Table 21. As can be seen, the first attribute level of financial consequences is significant with a coefficient of 1.052. This means that people in class 1 are willing to invest in solar panels by participating in a prosumer community. The second level of the financial consequences attribute shows a slight negative coefficient, but is not significant. The coefficient of the reference category is negative by -0.923, which is very likely to be significant. Furthermore, for the attribute levels of the attribute community involvement no significant differences can be identified, in which there is no preference for each of the levels. Moreover, in class 1, the coefficient of own control of appliances is 0.254 and is significant at the 5% level. In addition, the coefficient of the second level is slightly positive, but is not significant. However, the coefficient of the automatic control of appliances is negative by -0.455 and very likely to be significant. Finally, looking at the organizational participation, all attribute levels are not significant, but is seems that people do not prefer to be involved in organizational activities.

The coefficients for the alternative outsourcing of class 1 are also shown in Table 21. As can be seen, there are no significant attribute levels in the attributes financial consequences and community involvement, which means that the respondents have no preference for a particular level. Furthermore, the coefficient for own control of appliances is 0.332 and is significant at the 10% level. In addition, the automatic control level contains a negative coefficient of -0.375, which is very likely to be significant. There seems to be a pattern in which people prefer to control their appliances by their own instead of automatically. Finally, regarding the attribute organizational participations there is a slight preference for an active role in participating in a prosumer community, but this level is not significant. However, the coefficient of the third level, that contributes the reference category, is -0.294. This coefficient is probably significant and can be concluded that people in class 1 by outsourcing the activities do not prefer a passive role.

Results Class 2

Table 21 shows the results of class 2 that consists of more conservative respondents, starting with the own initiative alternative. As can be seen, the coefficient of the first level (solar panels) is 2.221 and is significant at the 1% level. Furthermore, the coefficients of the second level is slightly negative, but is not significant. However, the third level that represents the reference category has a negative coefficient of -1.603 and is very likely to be significant. This means that individuals in class 2 prefer the financial consequences of implementing solar panels instead of implementing solar panels, BTES system and an in-home battery by participating in a prosumer community. Secondly, the third level of the attribute community involvement represents the reference category; the coefficient is positive (0.572) and is very likely to be significant. The 25 and 50 percent participation levels are not significant. For the third attribute that concerns the control of appliances, the coefficient for the first level is positive (0.487) and significant at the 5% level. In addition, for the third level that represents the reference category, the coefficient is negative (-0.535) and is likely to be significant. This means people in class 2 prefer to control their appliances by their own instead of automatically by participating in a prosumer community. Finally, regarding the attribute own initiative, the coefficient of the minor participation level is 0.487 and significant at the 10% level. It can be concluded that people prefer to perform a minor participation role in participating in a prosumer community in the own initiative alternative.

For the alternative outsourcing, multiple attribute levels are significant, starting with the attribute financial consequences. It is worthwhile to note that compared to the results of class 1, people in class 2 strongly prefer the outsourcing alternative by implementing solar panels; the coefficient is equal to 1.137 and significant at the 1% level. The second level is slightly negative, but not significant. Looking at the third category that represents the reference category, the coefficient is negative (-0.942) and very likely to be significant. In the second attribute that contributes the community involvement, the 25 percent and 50 percent participation level are significant. The coefficient of the attribute level 25% participation is negative (-0.502) and for 50% participation it is positive (0.534). Remarkable is that the coefficient of 75 percent participation level is negative (-0.033). It was expected that when people strongly prefer 50 percent participation also prefer the 75 percent participation level. Subsequently, the coefficients of the attribute control of appliances correspond to the outcomes in class 1. It can therefore be concluded that people in class 2 prefer to control their appliances by their own instead of automatically by participating in a prosumer community. Finally, people in class 2 prefer to adopt a minor participation role by outsourcing the activities by participating in a prosumer community. The coefficient for this level is positive (0.368) and is significant at the 10% level. Furthermore, the coefficient of the active role level is negative (-0.483) and significant at the 5% level. It can be concluded that performing an active role by outsourcing the activities is not preferred by people in class 2.

Table 21 Results LCM classes

Attribute	Coefficients latent class 1 (enthusiasts)	Coefficient latent class 2 (conservatives)
N per class	109	75
Constant		
Constant 1	1.876***	-2.181***
Constant 2	1.763***	-1.856***
Alternative own initiative		
Solar panels	1.052***	2.221***
Solar panels and BTES system	-0.129	-0.618
Solar panels, BTES system, battery	-0.923	-1.603
25 percent participation	-0.152	-0.358
50 percent participation	0.131	-0.214
75 percent participation	0.021	0.572
Own control	0.254**	0.486**
Semi-Automatic controlled	0.201	0.049
Automatic controlled	-0.455	-0.535
Active role (4 hours / month)	-0.164	-0.333
Minor participation (2 hours / month)	-0.005	0.487*
Passive role (0-1 hours / month)	0.169	-0.154
Alternative outsourcing		
Solar panels	0.007	1.137***
Solar panels and BTES system	-0.002	-0.195
Solar panels, BTES system, battery	-0.005	-0.942
25 percent participation	-0.231	-0.501**
50 percent participation	0.072	0.534*
75 percent participation	0.159	-0.033
Own control	0.332*	0.409*
Semi-Automatic controlled	0.043	-0.036
Automatic controlled	-0.375	-0.373
Active role (4 hours / month)	0.217	-0.483**
Minor participation (2 hours / month)	0.077	0.368*
Passive role (0-1 hours / month)	-0.294	0.115

6.5.2 Descriptive analysis two classes

According to latent class analysis, two classes can be identified in showing similar choice behavior. For each respondent, NLogit provides the probability the respondent belongs to class 1 or class 2. The respondent can be assigned to the class with the highest probability. Subsequently, the class membership can be added to the database including the socio-demographic characteristics and environmental consciousness. As a result, 109 respondents are assigned to class 1 and 75 respondents are assigned to class 2. The next step is to gain more information of these classes based on their socio-demographic characteristics and environmental consciousness. The objective is to find out whether there is a relation between the variables and the cluster membership. To test whether these variables of the classes are independent of each other, cross tabs are obtained in SPSS. Given these crosstabs, the chi-square is determined to examine if the differences are significant. As a result, Table 22 and Table 23 presents the output of the cross tabs. The complete output of the cross tabs can be found in Appendix VII.

Table 22 includes the crosstab output of the personal characteristics of the respondents in each class. As a result, the variables age, education, property ownership and innovation adaptation are significant different. Based on the significant variables, differences between the socio-demographic characteristics of the two classes can be considered and described as follows.

Class 1 (enthusiasts)

In class 1, the age category consist of most people that are between 21 and 40 years and are higher educated compared to class 2. Furthermore, people in class 1 on average own their dwelling, but the share of renters is higher compared to class 2. Finally, people assign their self on average more as innovators, early adopters or early majority.

Class 2 (conservatives)

In class 2, the age category consist of most people that are older than 40 years compared to the averages of the levels and are lower educated than class 1. Moreover, people in class 2 on average own their dwelling and the share of renters is lower compared to class 2. Finally, people assign their self on average more as late majority or laggards.

Table 22 Socio demographic characteristics of LCM classes

Attribute	Attribute level	Frequency sample	% sample	Frequency Class 1	% Class 1	Frequency Class 2	% Class 2	Chi-square
Gender	Male	109	59.2%	69	63.3%	40	53.3%	.176
	Female	75	40.8%	40	36.7%	35	46.7%	
Age	21 to 30 years	60	32.6%	42	38.5%	18	24.0%	.037**
	31 to 40 years	37	20.1%	25	22.9%	12	16.0%	
	41 to 50 years	35	19.0%	18	16.5%	17	22.7%	
	> 50 years	52	28.3%	24	22.1%	28	37.3%	
Education	Secondary vocational education	63	34.2%	30	27.5%	33	44.0%	.046**
	Higher professional education	73	39.7%	50	45.9%	23	30.7%	
	Scientific education	48	26.1%	29	26.6%	19	25.3%	
Income	0 to 25000 euro	35	19.0%	18	16.5%	17	22.7%	.246
	25001 to 45000 euro	92	50.0%	60	55.1%	32	42.7%	
	> 45000 euro	57	31.0%	31	28.4%	26	34.7%	
Children	No children	107	58.2%	66	60.6%	41	54.7%	.427
	Children	77	41.8%	43	39.4%	34	45.3%	
Type of neighborhood	City center	38	20.7%	24	22.0%	14	18.7%	.576
	Outside center	54	29.3%	34	31.2%	20	26.7%	
	Village	92	50.0%	51	46.8%	41	54.7%	
Property ownership	Property owner	135	73.4%	75	68.8%	60	80.0%	.091*
	Property renter	49	26.6%	34	31.2%	15	20.0%	
Innovation adaptation	Innovators / early adopters	37	20.1%	27	24.8%	10	13.3%	.020**
	Early majority	86	46.7%	54	49.5%	32	42.7%	
	Late majority / laggards	61	33.2%	28	25.7%	33	44.0%	
Household composition	1-person household	19	10.3%	12	11.0%	7	9.3%	.942
	2-person household	81	44.0%	49	45.0%	32	42.7%	
	3-person household	34	18.5%	20	18.3%	14	18.7%	
	4-person household	50	27.2%	28	25.7%	22	29.3%	

In Table 23, the choice behavior of both classes regarding the environmental statements is presented. Looking at the chi-square, most statements are significant different from each other. According to the results, multiple conclusions can be drawn. First, in statement 3, there is a significant difference, in which it can be concluded that people in class 2 are less prepared to pay more for environmental friendly measures than people in class 1. Furthermore, it can be concluded that people in class 1 would like to be more independent of large energy providers than people in class 2. Subsequently, according to statement 6, people in class 1 are more willing to adopt a more environmental friendly lifestyle than people in class 2. When looking at the results of statement 7, it can be concluded that people in class 1 prefer to be seen with solar panels on their dwelling compared to people in class 2. Finally, people in class 1 strongly prefer to participate in a prosumer community compared to people in class 2. The statements that are not significant different are the statements 1, 2 and 4. According to these results, both classes agree and indicate that they are aware of the global climate issue. Overall, it can be concluded that people in class 1 have a more environmental conscious attitude than people in class 2. Therefore, in line with the results of the latent class model output, people in class 1 can be identified as enthusiast and people in class 2 as conservatives.

Table 23 Environmental statements of LCM classes

Statement	Attribute level	Frequency sample	% sample	Frequency Class 1	% Class 1	Frequency Class 2	% Class 2	Chi-square
Statement 1	Agree	141	76.6%	82	75.2%	59	78.7%	.753
I am worried about global	Neutral	29	15.8%	19	17.4%	10	13.3%	
warming	Disagree	14	7.6%	8	7.3%	6	8.0%	
Statement 2	Agree	151	82.1%	89	81.7%	62	82.7%	.504
The majority of the population is	Neutral	24	13.0%	16	14.7%	8	10.7%	
not acting environmental conscious	Disagree	9	4.9%	4	3.7%	5	6.7%	
Statement 3	Agree	96	52.2%	65	59.6%	31	41.3%	.019**
I am prepared to pay more for	Neutral	60	32.6%	33	30.3%	27	36.0%	
environmental friendly measures	Disagree	28	15.2%	11	10.1%	17	22.7%	
Statement 4	Agree	156	84.8%	94	86.2%	62	82.7%	.636
The government should take	Neutral	23	12.5%	13	11.9%	10	13.3%	
more action against the climate problem	Disagree	5	2.7%	2	1.8%	3	4.0%	
Statement 5	Agree	101	54.9%	72	66.1%	29	38.7%	.000***
I would like to be more	Neutral	51	27.7%	26	23.9%	25	33.3%	
independent of large energy providers	Disagree	32	17.4%	11	10.1%	21	28.0%	
Statement 6	Agree	145	78.8%	97	89.0%	48	64.0%	.000***
I am willing to adopt a more	Neutral	35	19.0%	11	10.1%	24	32.0%	
environmental friendly lifestyle	Disagree	4	2.2%	1	0.9%	3	4.0%	
Statement 7	Agree	90	48.9%	68	62.4%	22	29.3%	.000***
I would like to be seen with solar	Neutral	53	18.8%	33	30.3%	20	26.7%	
panels on my dwelling	Disagree	41	22.3%	8	7.3%	33	44.0%	
Statement 8	Agree	124	67.4%	86	78.9%	38	42.6%	.000***
I would participate in a	Neutral	42	22.8%	21	19.3%	21	28.0%	
prosumer community	Disagree	18	9.8%	2	1.8%	16	21.3%	

6.6 ANALYSIS FINANCIAL CONSEQUENSES

In this section, the additional question regarding the financial consequences per choice set is analyzed. The attribute financial consequences was describes by three aspects: initial investment, financial savings per year and payback time / contract time. By means of an additional question, insight was gained which financial aspects people's choices were based on. Respondents were allowed to select multiple aspects. The question was defined as follow: *"Which of the aspects of financial consequences were influential in your choice? (multiple choices are possible):*

- ☐ *Investment implementations (solar panels, BTES system, in-home battery)*
- ☐ *Financial savings per year*
- ☐ *Payback/contracting period*
- ☐ *None of these"*

To determine the important financial decisive motivational factors, the dataset was divided based on the three alternatives. Subsequently, per alternative the choice sets were selected that contains the same attribute level of the attribute financial consequences. In the choice experiment, three attribute level of the attribute financial consequences were presented to the respondents: solar panels (level 1), solar panels and BTES system (level 2), solar panels, BTES system and in-home battery (level 3). From these results, the frequencies in which people choose for investment implementations, financial savings per year etc. are considered. In Figure 22, the results of the multiple financial aspects for the alternative own initiative are presented. According to the results, multiple conclusions can be drawn. First, the lower investment costs of level 1 is more influential for the decision of respondents compared to levels 2 and 3. Furthermore, financial savings per year were found important for all attribute-levels. It can be concluded that this is the most important aspect in people's decision. Moreover, the short payback period of level 1 positively influenced people's decision. The long payback period of level 2 and 3 is less frequently mentioned. Finally, on average, for a small number of respondents, the 'none of these' option was selected. This means that people considered a different decisive factor rather than the attribute levels.

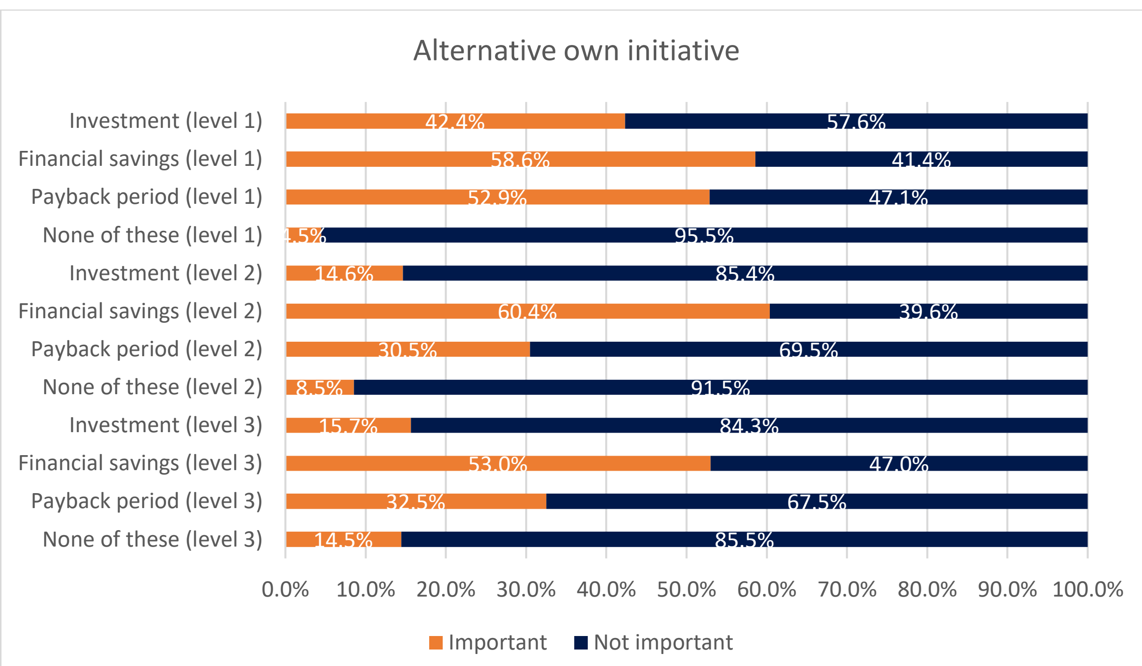

Figure 22 Financial consequence aspects own initiative

In Figure 23, the results of the attribute levels for the alternative outsourcing are presented. As can be seen, the outsourcing of the initial investment is for all attribute levels the most decisive aspect in people's decision to choose for the alternative outsourcing. Furthermore, the small financial savings that are obtained do not have much effect on people's decision. Moreover, the contract period of level 1 is more preferred than for level 2 and 3. This can be attributed to the short contract period in the case of level 1 compared to the other levels. Finally, it can be concluded that the share of 'no preference' for the financial consequences aspects in all levels is relatively small.

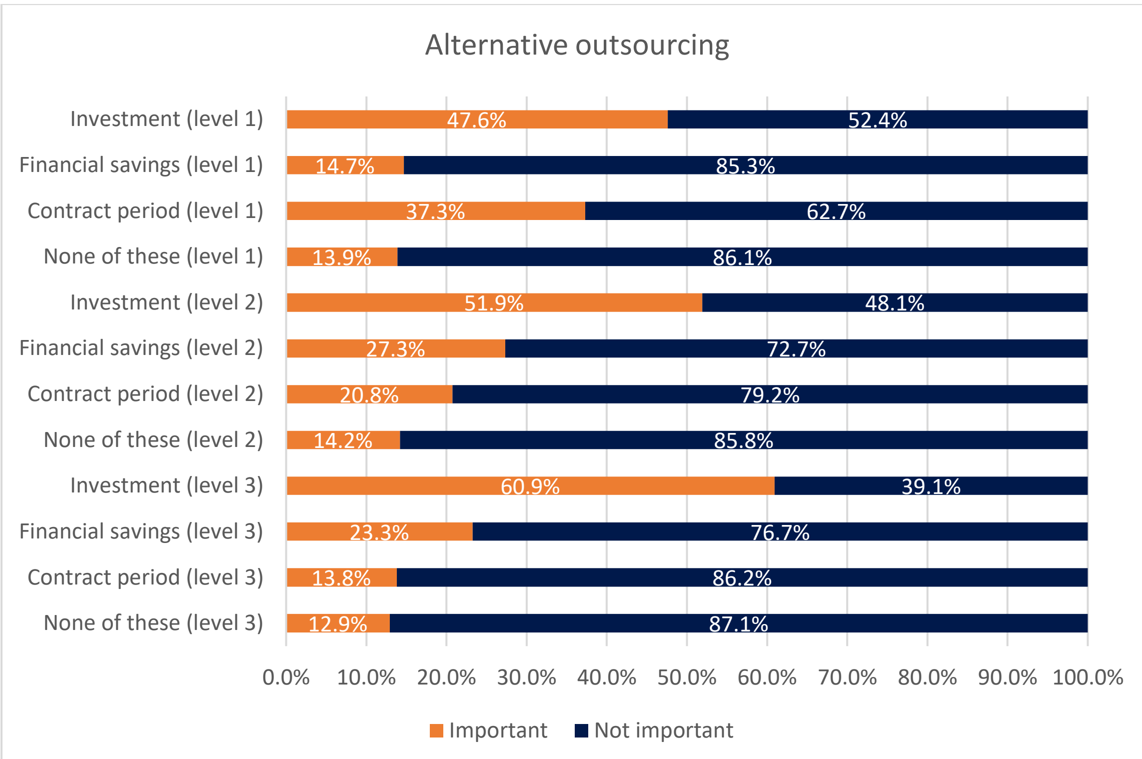

Figure 23 Financial consequence aspects outsourcing

In Figure 24, the aspects of the financial consequences of the alternative none of these are presented. As can be seen, it appears that the payback / contracting period is more decisive in people's decision than the other two aspects. However, the 'none of these' was selected most frequently which means that people considered a different decisive factor rather than the financial attribute levels.

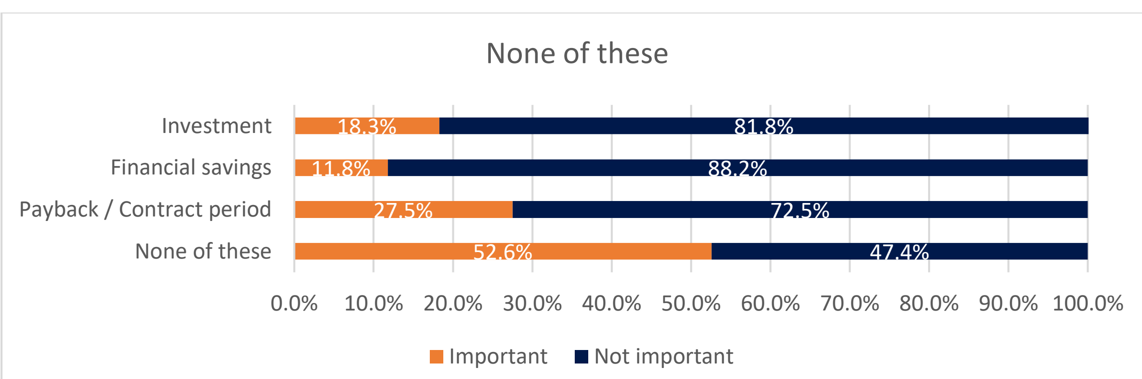

Figure 24 Financial consequence aspects none of these

6.7 CONCLUSION

This chapter focused on the choice behavior of individuals to find out which attributes were decisive in people's decision to participate in a prosumer community. The data collection took place in May 2018. After two weeks of data collection, 184 respondents finished the questionnaire completely. In this chapter, the output of the questionnaire is analyzed according to different statistical approaches. First, the sample was described and compared to the Dutch population. Only the sample's gender distribution appeared to be representative to the Dutch population.

In the second part of the analysis, the results of the eight environmental statements were combined with the social-demographic characteristics of the respondents by means of crosstabs. On average, it can be concluded that the majority of the sample agreed on all statements, which means that the sample has an environmental conscious attitude. However, people between 31 and 50 years, who are higher educated, or have an income above 25.000 euro are more prepared to pay more for environmental friendly measures than their counterparts. Furthermore, it appears that higher educated people would more like to be seen with solar panels on their house and are more willing to participate in a prosumer community than lower educated people.

In the third part of the analysis, the stated choice data was analyzed. The stated choice experiment focusses on choice behavior of individuals to find out which attributes are decisive in people's decision to participate in a prosumer community. First, the multinomial logit model was applied to the full sample. According to the results, multiple conclusions can be drawn. First, for the alternative own initiative and alternative outsourcing, it can be concluded that people prefer the financial consequences of implementing only solar panels instead of the financial consequences of implementing solar panels, BTES system and in-home battery. Secondly, for both alternatives, it can be concluded that there is a significant preference for own control of appliances instead of automatic control. Thirdly, for both alternatives, there is a pattern in which people do not prefer to be involved in organizational activities. Finally, for the alternative outsourcing, it can be concluded that people are less prepared to participate in a prosumer community and outsource their investment when only 25 percent of the neighborhood is being involved. However, for both alternatives, the 75 participation level is preferred.

In the final part of the analysis, the latent class model is used to discover clusters of respondents in the sample. The clusters of individuals share similar choice behavior. According to this model, two classes could be found in which in class 1 (109 respondents) the constants for the two main alternatives are positive and in class 2 (75 respondents) the constants are negative. First, in both classes for the alternative own initiative, it can be concluded that people prefer the financial consequences of implementing only solar panels instead of the financial consequences of implementing solar panels, BTES system and in-home battery. However, class 2 significantly prefers implementing solar panels by outsourcing the activities. Furthermore, for both classes, it can be concluded that there is a significant preference for own control of appliances instead of automatic control. Focusing on the attribute organizational participation, it can be noticed that people in class 2 significantly prefer a minor participation role rather than performing an active role. Finally, people in class 2 significantly prefer a 50 percent community involvement when the activities of participating a prosumer community are outsourced.

Furthermore, to gain more insight in the two classes, the socio-demographic characteristics and people's choice behavior regarding the environmental statements are examined for both classes. To test whether two attributes of the classes are independent of each other, cross tabs are executed in SPSS. Given these crosstabs, the chi-square is determined to examine if the differences are significant. As a result, the socio-demographic characteristics age, education, property ownership and innovation adaptation are significant different. For the environmental statements, the classes are significant different in five of the eight statements. According to these results, it seems that people in class 1 have a more environmental conscious attitude than class 2, which is in line with the results of the latent class analysis.

Finally, from the analysis regarding the additional question concerning the financial consequences, multiple conclusions can be drawn. First, it can be concluded that in the alternative own initiative, people's decision is mainly based on the financial savings per year. In addition, people prefer a lower initial investment and a short payback period. Secondly, when people choose for the alternative outsourcing, the outsourcing of the initial investments seems to be decisive in people's decision. The small financial savings that can be obtained per year appears to be not very influential. Furthermore, when people choose for the alternative none of these, their decision is mainly based on different decisive factors rather than the attribute levels.

7 CONCLUSION

This thesis conceptualizes a prosumer community as a potential development in the changing energy landscape and pertains to the integration and community engagement of local citizens to participate in a prosumer community. The research focusses on the individual and collective technical needs, the financial feasibility and the main decisive motivations of individuals given socio-demographic characteristics. With this background, the scientific and social relevant conclusions can be drawn. For the scientific relevance, the four sub questions are explained that contribute to the main question. Furthermore, recommendations for future research and for stakeholders in this field are provided. Finally, the recommendations are discussed, based on the limitations of this project.

7.1 SCIENTIFIC RELEVANCE

This study mainly contributes to the knowledge of integration and community engagement in local energy initiatives as prosumer communities. The existing literature was reviewed to identify the most important factors that influences energy curtailment and investment behavior given socio-demographic characteristics. However, less research is conducted on how this knowledge can be applied in the Dutch situation and to what extend people are willing to participate in a prosumer community. Therefore, this research project adds knowledge about main decisive motivations of people to participate in a prosumer community to the existing literature and explains the technical and financial needs that are of importance for the integration of decentralized energy generation in the built environment.

SQ1. What are the technological needs to realize a prosumer community at the individual and community level?

In order to realize a prosumer community, multiple technologies need to be implemented at the individual and collective level. In line with the ambition of the Dutch government, the concept of a prosumer community include energy efficient implementations that are not powered by gas, but are full-electric to provide the heating, cooling and electricity demand. With these means, the usage of fossil energy is decreased and a larger share of renewable energy sources is obtained. For the energy efficient implementations at the technical level, assumptions are made regarding a prosumer community, both at the individual and collective level based on a high energetic performance, general suitability and future potential. At the collective level, the heating and cooling demand of a dwelling can be generated by an aquifer thermal energy storage system. When there is no operator that exploits land for a collective aquifer, an individual closed-loop borehole thermal energy storage system is proposed. The electricity demand for the heat pump and the household consumption is mainly generated by solar panels that are implemented at each dwelling. The objective of a prosumer community is to maintain the energy generated as much as possible in the community. By implementing demand side management software in a prosumer community, the production and consumption of energy in the neighborhood can be managed. When there is an excess of energy, prosumers can sell their energy to people who prefer sustainable energy. This system can be combined with storage devices, in which it becomes possible to store energy surplus. This reduces the need for importing energy from the main energy grid. However, a complete independency from the main energy grid is not achievable, because of seasonal fluctuations. In conclusion, the concept of a prosumer community described in this research adds a new elaboration to the existing literature in being full-electric powered to provide the heating, cooling and electricity demand that also meets the ambition of the Dutch government.

SQ2. To what extent can a prosumer community be financially optimized?

To gain a complete overview of all aspects for realizing a prosumer community, is of importance to gain insight in the financial consequences. At first, it can be concluded that according to the energy price expectations, the gas price and the fossil energy price will rise in the future. Due to these rising prices, investing in energy efficient implementations becomes more financial attractive on a long term. To overcome the high initial investment costs, it can be concluded that there are two approaches: investment by collective individuals or outsourcing by an Energy Service Company. Collective investments by individuals results in more financial savings and negotiation power. When people do not have the financial resources or knowledge to realize energy efficient implementations at their dwelling, ESCO outsourcing can be a potential solution. By applying this approach, the ESCO company takes the financial risk and people can be satisfied by generating their own renewable energy. In order to provide a complete substantiated overview of the financial consequences, a financial analysis has been executed for an EPC 0.4 dwelling, BENG dwelling and prosumer dwelling. In this analysis, the BENG and prosumer scenario have been compared to the current EPC 0.4 requirements. As can be concluded from the financial analysis, reasonable financial savings can be obtained in the BENG and prosumer scenario by implementing a borehole thermal energy storage system. However, because of the high initial investment and re-investment costs, these scenarios are not becoming financially feasible compared to a dwelling based on the current EPC 0.4 requirements. All in all, when deciding to invest in high energetic efficiency implementations for future dwellings, the pro-environmental attitude and the willingness to generate renewable energy should be more a decisive motivation for individuals to participate in a prosumer community than looking at the financial feasibility.

SQ3. What are the decisive motivational factors for people to participate in a prosumer community?

According to the literature review, consumers' behavior is dependent on attitude and awareness, financial consequences, peer pressure and social identity. In this research, a stated choice experiment is executed in which a questionnaire is distributed. In this questionnaire, two alternatives are repeatedly presented to the respondents: own initiative or outsourcing of the energy efficient implementations. According to the results, multiple conclusions regarding people's decisive motivational factors for participating in a prosumer community can be drawn. First, for both alternatives, it can be concluded that people prefer the financial consequences of a low initial investment, moderate financial savings per year and a short payback period / contract duration instead of a large initial investment that results in reasonable financial savings each year, but have a longer payback period / contract duration. Secondly, it can be concluded that there is a significant preference in both alternatives for own control of appliances instead of automatic control. According to this result, the level of comfort in controlling appliances is found to be an important decisive motivational factor. Thirdly, for both alternatives, there is a pattern in which people do not prefer to be involved in organizational activities when questioning the organizational participation. By focusing on the levels, a passive or minor participation role is significantly preferred over performing an active role. Finally, for the alternative outsourcing, it can be concluded that people are less willing to participate in a prosumer community and outsource their investment when only 25 percent of the neighborhood is being involved. However, for both alternatives, the 75 participation level is preferred. Community involvement is therefore found as a decisive motivational factor.

SQ4. To what extent is the willingness of Dutch citizens to participate in a prosumer community influenced by decisive motivational factors?

When considering the influence of decisive motivational factors on the overall willingness of people to participate in a prosumer community, few conclusions can be drawn. According to the constant in the overall model, no specific preference can be identified for the own initiative or outsourcing alternative. Therefore, it is decided to execute a latent class model analysis to discover clusters that have a corresponding choice behavior. As a result, two classes could be identified. In class 1, people are more willing to participate in a prosumer community and prefer to realize the investment by their own. On the other hand, significant evidence is found that people in class 2 are less willing to participate in a prosumer community, but if they do, they are equally divided in realizing the investment by their own or outsource the energy efficient implementations. Furthermore, people in class 2 are significantly less willing to perform an active role and prefer a minor participation role compared to people in class 1. In addition, people in class 2 prefer a 50 percent participation when the activities are outsourced. Moreover, both classes share the preference of controlling their appliances by their own instead of automatically by a system. It can be concluded that people in class 1 can be identified as enthusiasts and people in class 2 as more conservative. To answer SQ4, the willingness of local citizens that is influenced by decisive motivational factors is divided in two clusters that differ in terms of the socio-demographic characteristics and environmental conscious attitude of the individual. By examining the choice behavior of both classes on the environmental statements, it can be concluded that people in class 1 seems to have a more environmental conscious attitude than class 2, which is in line with the results of the latent class analysis output.

MQ. To what extent are Dutch citizens willing to participate in a prosumer community?

For answering the research question, the literature on energy curtailment and investment behavior is reviewed and a stated choice experiment is executed. According to the estimated models, it can be concluded that there is support from Dutch citizens to generate their own energy and adopt a more energy-saving behavior. However, the extent of willingness to participate in a prosumer community is significantly dependent on the financial consequences of implementing energy efficient measures, a large share of the community that is involved, own control of appliances instead of automatically by a system and less involvement in organizational activities. Furthermore, it is of importance to focus on people based on their socio-demographic characteristics and environmental conscious attitude. Regarding the socio-demographic characteristics, people between 21 and 40 years that are higher educated, who own their dwelling and assign their self on average more as innovators, early adopters or early majority can be identified as enthusiastic to participate in a prosumer community. Moreover, based on the environmental statements, people that are willing to pay more for environmental friendly measures, prefer to be independent from large energy providers, willing to adopt a more environmental friendly lifestyle and prefer to be seen with solar panels on the dwelling are more willing to participate in a prosumer community. All in all, the extent of Dutch citizens to participate in a prosumer community is dependent on people’s importance level of decisive motivational factors, socio-demographic characteristics and environmental conscious attitude.

7.2 SOCIETAL RELEVANCE

By focusing on the current policy regarding the encouragement of energy efficient measures by individuals by the Dutch government, energy transition is becoming a more urgent issue. The Dutch government is aware that a change is essential to achieve the set goals of reducing the greenhouse gases and increase the share of renewable energy sources. As can be concluded, the integration of decentralized generation in the built environment like prosumer communities can be a potential solution for Dutch cities to become energy neutral. All in all, it seems that Dutch citizens have on average a pro-environmental attitude, which results in that they are willing to adopt a more environmental friendly behavior or are willing to pay more for environmental friendly measures. Furthermore, according to the results, there is support from individuals to participate in a prosumer community. With this background, it can be concluded that the energy transition in the Netherlands can be speed up. However, in this encouragement, it is of importance that the main decisive motivational factors based on socio-demographic characteristics are considered. Especially, in deciding to develop a prosumer community, identifying and attracting the right target group is essential. According to the results of this research, enthusiasts and conservatives can be divided based on socio-demographic characteristics. To conclude, for the realization of a prosumer community, enthusiasts need to be identified and encouraged as initiators in setting-up or participating in a prosumer community. Furthermore, the Dutch government should financially support more high energetic efficiency alternatives like borehole thermal energy storage systems and in-home batteries to overcome the high initial investment costs. As can be concluded, the high initial investment costs that results in a long payback period, avoid people to choose for alternatives without gas demand. Therefore, the general advice to increase the support of people to participate in a prosumer community, full-electric powered energy efficient implementations need to be encouraged by financial incentives.

7.3 DISCUSSION AND RECOMMENDATIONS

Finally, some recommendations can be formulated that emerge for related stakeholders of this topic and for possible future research, based on the limitations of this research. First, it is recommended to provide a more detailed technical elaboration of a prosumer community. This research only focusses on how different energy efficient implementations can be applied, but not how multiple households can be interconnected at the detailed technical level. Therefore, research should be conducted on how smart grids can be designed in which decentralized produced energy can be better distributed in the community. In addition, further research should be obtained regarding the technical execution of demand side management software that regulates the energy production and consumption. In the current literature, it is not clear what the effect is of demand side management software on households and what net benefits can be obtained by a prosumer community. Moreover, this research is limited on providing in-depth research on the control of appliances and how these should be optimally arranged in combination with the energy generation of solar panels. Furthermore, no research is available on how in-home batteries can be implemented at multiple dwellings. Further research can be executed on the potential of in-home batteries in the Netherlands when the 'salderen' policy is abolished.

Secondly, a more detailed research on the commercial benefits of realizing prosumer community should be conducted. In this thesis, a hypothetical situation for an individual dwelling is assumed. However, for a more elaborated business case, the technical elaboration should be more detailed at the community level. In this business case, scenarios should be sketched on the effect of energy price expectations, scale benefits of collective investments should be determined and commercial net benefits should be calculated by energy selling to other dwellings in the grid. In addition, in future research the financial benefits regarding the attribute levels of control of appliances can be determined, which might have a positive influence on people's choice behavior to choose for an automatic control. Furthermore, research can be conducted on the potential for Energy Service Companies to invest in these communities. These firms can overcome barriers like high initial investment costs, lack of knowledge that many individuals have regarding large energy efficient implementations and can take away the financial risk, which all have a negative influence on the decision behavior of individuals.

Finally, recommendations can be provided according to the limitations of the stated choice experiment. The sample does not represent the Dutch population. Therefore, it is recommended that a larger and more representative sample is involved. Furthermore, according to the results, the attribute levels that contains a borehole thermal energy storage system and in-home battery have a negative influence on people's choice behavior. This negative influence might not only be attributed to the financial consequences, but can arise from a lack of knowledge of potential benefits. Therefore, the research is limited on the question if lack of knowledge is a decisive motivational factor in people's decision. Moreover, further research on decisive motivational factors is necessary that focusses on people that already live in collective energy initiative. These results can be compared to the conclusions of this research in which it can be examined if the choice behavior outcomes and the socio-demographic characteristics correspond. Finally, a more in-depth research can be conducted on how conservatives and skeptics can be persuaded to participate in a prosumer community. In the aspiration of cities to achieve the goal of becoming energy neutral, the late majority and the laggards should also be included.

REFERENCES

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households ' direct and indirect energy use and savings ? *Journal of Economic Psychology*, *30*(5), 711–720. https://doi.org/10.1016/j.joep.2009.05.006

Ali, A. B. M. S. (2013). *Smart Grids: Opportunities, Developments, and Trends*. Springer Energy.

Banfi, S., Farsi, M., Filippini, M., & Jakob, M. (2008). Willingness to pay for energy-saving measures in residential buildings. *Energy Economics*, *30*(2), 503–516. https://doi.org/10.1016/j.eneco.2006.06.001

Barr, S., Gilg, A. W., & Ford, N. (2005). The household energy gap: Examining the divide between habitual- and purchase-related conservation behaviours. *Energy Policy*, *33*(11), 1425–1444. https://doi.org/10.1016/j.enpol.2003.12.016

Barreto, M. L., Szóstek, A., Karapanos, E., Nunes, N. J., Pereira, L., & Quintal, F. (2014). Understanding families' motivations for sustainable behaviors. *Computers in Human Behavior*, *40*, 6–15. https://doi.org/10.1016/j.chb.2014.07.042

CBS. (2014). *Income and disposability*. Retrieved from Visualization CBS: http://visualisatie.cbs.nl/nl-NL/Visualisation/Inkomensverdeling

CBS. (2016). *Four in ten households live in a terraced house*. Retrieved from CBS: https://www.cbs.nl/nl-nl/nieuws/2016/14/vier-op-de-tien-huishoudens-wonen-in-een-rijtjeshuis

CBS. (2016). *Households; number of children, age group child, region, 1 January*. Retrieved from StatLine CBS: http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=71487NED

CBS. (2017). *Households; composition, size, region, January 1st*. Retrieved from StatLine CBS: http://statline.cbs.nl/statweb/publication/?vw=t&dm=slnl&pa=71486ned&d1=0-2,23-26&d2=0&d3=0,5-16&d4=(l-1)-l&hd=090402-0910&hdr=t,g3&stb=g1,g2

CBS. (2017). *Inventory homes; property, type of landlord, occupation, region*. Retrieved from StatLine CBS: http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82900NED&D1=a&D2=0&D3=0,75,187,361,412&D4=a&HDR=T&STB=G1,G2,G3&VW=T

CBS. (2017). *Renewable energy source distribution to 5.9% in 2016*. Retrieved from CBS: https://www.cbs.nl/nl-nl/nieuws/2017/22/aandeel-hernieuwbare-energie-5-9-procent-in-2016

CBS. (2017). *Statline energy usage households*. Retrieved from CBS: http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=82375NED

CBS. (2018). *Population: gender, age and migration background*. Retrieved from Opendata CBS: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37325/table?ts=1526990460136

Behrangrad, M. (2015). A review of demand side management business models in the electricity market. *Renewable and Sustainable Energy Reviews*, *47*, 270–283. https://doi.org/10.1016/j.rser.2015.03.033

Berendsen, I. J. A., & Roza, E. (2010). *Being environmentally conscious and environmentally aware?* University of Utrecht.

Bertoldi, P., Hinnells, M., & Rezessy, S. (2006). Liberating the power of Energy Services and ESCOs in a liberalised energy market. *International Energy Efficient Domestic Appliances and Lighting Conference*, *1*, 21–32. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC33747

Bouwens, C. (2017). Woningbouw volgens BENG. *Lente Akkoord*, pp. 1–24. Retrieved from https://www.lente-akkoord.nl/wp.../Lente-akkoord-Woningbouw-volgens-BENG.pdf

Das, R., Richman, R., & Brown, C. (2017). Demographic determinants of Canada ' s households ' adoption of energy efficiency measures : observations from the Households and Environment Survey , 2013. *Energy Efficiency*, 465–482. https://doi.org/10.1007/s12053-017-9578-4

Dekker, P., Ridder, J. Den, van Houwelingen, P., & van den Broek, A. Burgerperspectieven 2016 | 4 (2016). Retrieved from https://www.scp.nl/Publicaties/Alle_publicaties/Publicaties_2016/Burgerperspectieven_2016_4

Energieonderzoek Centrum Nederland (ECN). (2017). *Nationale Energieverkenning 2017*. Retrieved from http://www.cbs.nl/NR/rdonlyres/C0F1D74C-1EB1-4E3B-9A46-ECA28ABFED7E/0/2015nationaleenergieverkenning.pdf

Europadecentraal. (2017, March 20). *Renewable energy sources share of 17% in the EU* . Retrieved from Europadecentraal: https://europadecentraal.nl/aandeel-hernieuwbare-energie-in-de-eu-op-bijna-17-procent/

Feng, T., Arentze, T., & Timmermans, H. (2010). Capturing Preference Heterogeneity of Truck Drivers ' Route Choice Behavior With Context Effects Using a Latent Class Model. *European Journal of Transport and Infrastructure Research*, *13*(4), 1–15.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). The Socio-Demographic and Psychological Predictors of Residential Energy Consumption: A Comprehensive Review. *Energies*, *8*(1), 573–609. https://doi.org/10.3390/en8010573

Gensch, H., Recker, D., & Recker, W. (1979). The Multinomial, Multiattribute Logit Choice Model. *Journal of Marketing Research*, *14*(1), 124–132. https://doi.org/10.2307/3150883

Gillingham, K., Rapson, D., & Wagner, G. (2016). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy*, *10*(1), 68–88. https://doi.org/10.1093/reep/rev017

Gliem, J. A., & Gliem, R. R. (2003). Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education*, 82–88. https://doi.org/10.1109/PROC.1975.9792

Han, Q., Nieuwenhijsen, I., Vries, B. De, Blokhuis, E., & Schaefer, W. (2013). Intervention strategy to stimulate energy-saving behavior of local residents. *Energy Policy*, *52*, 706–715. https://doi.org/10.1016/j.enpol.2012.10.031

Hansen, M., & Hauge, B. (2017). Prosumers and smart grid technologies in Denmark: developing user competences in smart grid households. *Energy Efficiency*, *10*(5), 1215–1234. https://doi.org/10.1007/s12053-017-9514-7

Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). *Applied Choice Analysis: A Primer*. Cambridge University Press. https://doi.org/10.1017/CBO9780511610356

IBM. (2018). *TwoStep Cluster Analysis*. Retrieved from IBC Knowlegde center: https://www.ibm.com/support/knowledgecenter/en/SSLVMB_24.0.0/spss/base/idh_twostep_main.html

ING Economisch Bureau. (2013). *Hand in hand naar energie neutrale gebouwen*. Retrieved from https://www.ing.nl/media/ING_hand-in-hand-naar-energie-neutrale-gebouwen-september-2013_tcm162-73838.pdf

Kemperman, A. D. A. M. (2000). *Temporal aspects of theme park choice behavior : modeling variety seeking, seasonality and diversification to support theme park planning*. Eindhoven University of Technology. https://doi.org/10.6100/IR542240

Kesting, S., & Bliek, F. (2013). *From Consumer to Prosumer: Netherland's PowerMatching City Shows The Way*. *Energy Efficiency* (First Edit). Elsevier Inc. https://doi.org/10.1016/B978-0-12-397879-0.00014-1

Koirala, B. (2017). *Integrated Community Energy Systems*. *TU Delft University*. https://doi.org/10.4233/uuid:10d555dd-8f03-4986-b5bf-ef09a63c92e1

Kuh, K. F. (2012). When Government Intrudes: Regulating Individual Behaviors That Harm the Environment. *Duke Law Journal*, *61*(6), 1111–1181. Retrieved from https://ezproxy.southern.edu/login?qurl=http%3A%2F%2Fsearch.ebscohost.com%2Flogin.aspx%3Fdirect%3Dtrue%26db%3Da9h%26AN%3D74026866%26site%3Dehost-live%26scope%3Dsite

Lee, D. (2013). A comparison of choice-based landscape preference models between British and Korean visitors to National Parks. *Life Science Journal*, *10*(2), 2028–2036. https://doi.org/10.1017/CBO9781107415324.004

Lee, K. S. (2013). *Underground thermal energy storage*. *Springer*. London: Springer Energy. https://doi.org/10.1007/978-1-4471-4273-7

Leiva, J., Palacios, A., & Aguado, J. A. (2016). Smart metering trends, implications and necessities: A policy review. *Renewable and Sustainable Energy Reviews*, *55*, 227–233. https://doi.org/10.1016/j.rser.2015.11.002

Lin, S. (2015). Raising Public Awareness : The Role of the Household Sector in Mitigating Climate Change, 13162–13178. https://doi.org/10.3390/ijerph121013162

Mangold, D., & Deschaintre, L. (2015). *Seasonal thermal energy storage: Report on state of the art and necessary further R+D*. Retrieved from http://task45.iea-shc.org/fact-sheets

Marino, a, Bertoldi, P., Rezessy, S., & Boza-Kiss, B. (2010). *Energy Service Companies Market in Europe*. *Status Report*. https://doi.org/10.2788/8693

Ministry of Education, Culture and Science . (2017). *Dutch education system*. Retrieved from Education in numbers: https://www.onderwijsincijfers.nl/kengetallen/sectoroverstijgend/nederlands-onderwijsstelsel/hoogst-behaalde-onderwijsniveau

NHG. (2018). *Energy-saving measures*. Retrieved from National Loan Guarantee (NHG): https://www.nhg.nl/Professional/Advies-en-verstrekking/EBV

Nijssen, E. J. (2017). *Entrepreneurial Marketing* (2nd New ed). Taylor & Francis Ltd.

Nordell, B., Snijders, A., & Stiles, L. (2015). *The use of aquifers as thermal energy storage (TES) systems*. *Advances in Thermal Energy Storage Systems: Methods and Applications*. Stuttgart, Germany: Woodhead Publishing Limited. https://doi.org/10.1533/9781782420965.1.87

Nuiten, P., Goud, J., Hoiting, H., Ree, B. Van Der, Harmelink, M., Bosselaar, L., & Rienstra, J. (2017). Uniforme Maatlat Gebouwde Omgeving (UMGO) voor de warmtevoorziening in de woning - en utiliteitsbouw, 1–73.

Pal, R., Chelmis, C., Frincu, M., & Prasanna, V. (2016). MATCH for the Prosumer Smart Grid the Algorithmics of Real-Time Power Balance. *IEEE Transactions on Parallel and Distributed Systems*, *27*(12), 3532–3546. https://doi.org/10.1109/TPDS.2016.2544316

Platt, G., Berry, A., & Cornforth, D. J. (2012). *What Role for Microgrids? Smart Grid*. Elsevier Inc, 185-207. https://doi.org/10.1016/B978-0-12-386452-9.00008-5

Poruschi, L., & Ambrey, C. L. (2016). On the confluence of city living, energy saving behaviours and direct residential energy consumption. *Environmental Science and Policy*, *66*, 334–343. https://doi.org/10.1016/j.envsci.2016.07.003

Prakash, L., Kumari P.R., S., Chandran, S., Kumar S., S., & Soman K.P. (2015). Self-sufficient Smart Prosumers of Tomorrow. *Procedia Technology*, *21*, 338–344. https://doi.org/10.1016/j.protcy.2015.10.044

Rathnayaka, A. J. D., Potdar, V. M., Dillon, T., Hussain, O., & Kuruppu, S. (2014). Goal-oriented prosumer community groups for the smart grid. *IEEE Technology and Society Magazine*, *33*(1), 41–48. https://doi.org/10.1109/MTS.2014.2301859

Rathnayaka, A. J. D., Potdar, V. M., Dillon, T. S., Hussain, O. K., & Chang, E. (2014). A methodology to find influential prosumers in prosumer community groups. *IEEE Transactions on Industrial Informatics*, *10*(1), 706–713. https://doi.org/10.1109/TII.2013.2257803

Razzaq, S., Zafar, R., Khan, N., Butt, A., & Mahmood, A. (2016). A Novel Prosumer-Based Energy Sharing and Management (PESM) Approach for Cooperative Demand Side Management (DSM) in Smart Grid. *Applied Sciences*, *6*(10), 275. https://doi.org/10.3390/app6100275

Ren21. (2013). *Renewables - Global futures report 2013*. Retrieved from http://www.ren21.net/Portals/0/documents/activities/gfr/REN21_GFR_2013.pdf

Rijksdienst voor Ondernemend Nederland (RVO). (2015). *Gerealiseerde Nieuwbouw Woningen met EPC < 0,4*. Retrieved from https://www.rvo.nl/sites/default/files/2015/01/Gerealiseerde Nieuwbouw Woningen EPC kleiner 0 4.pdf

Rodríguez-Molina, J., Martínez-Núñez, M., Martínez, J. F., & Pérez-Aguiar, W. (2014). Business models in the smart grid: Challenges, opportunities and proposals for prosumer profitability. *Energies*, *7*(9), 6142–6171. https://doi.org/10.3390/en7096142

Rogers, E. M. (1995). *Diffusion of innovations*. *Macmillian Publishing Co.* New York: Free Press.

RVO. (2015). *Innovatiethema Energiebesparing in de Gebouwde Omgeving*. Retrieved from https://www.topsectorenergie.nl/sites/default/files/uploads/Urban energy/adocumenten/Innovatiethema Energiebesparing in de Gebouwde Omgeving.pdf

RVO. (2018). *Subsidies and Financing*. Retrieved from Netherlands Enterprise Agency (RVO):

https://www.rvo.nl/subsidies-regelingen

Sardianou, E., & Genoudi, P. (2013). Which factors affect the willingness of consumers to adopt renewable energies ? *Renewable Energy*, *57*, 1–4. https://doi.org/10.1016/j.renene.2013.01.031

Schweizer-Ries, P. (2008). Energy sustainable communities: Environmental psychological investigations. *Energy Policy*, *36*(11), 4126–4135. https://doi.org/10.1016/j.enpol.2008.06.021

Sharma, S., Jain, K. K., & Sharma, A. (2015). Solar Cells : In Research and Applications — A Review. *Materials Sciences and Applications*, *6*, 1145–1155. https://doi.org/10.4236/msa.2015.612113

Sociaal-Economische Raad. (2013). *Energieakkoord voor duurzame groei*. Retrieved from https://www.ser.nl/~/media/files/internet/publicaties/overige/2010_2019/2013/energieakkoord-duurzame-groei/energieakkoord-duurzame-groei.ashx

Stedin. (2018). *Prices of net costs*. Retrieved from Stedin: https://www.stedin.net/tarieven

Sweco. (2017). *Duurzame energieoplossingen Keijzershof en Tuindershof te Pijnacker Verantwoording Titel E-mailadres Gecontroleerd door Paraaf gecontroleerd Benny Roelse Goedgekeurd door Paraaf goedgekeurd*. De Bilt.

Udalov, V., Perret, J., & Vasseur, V. (2017). Environmental motivations behind individuals' energy efficiency investments and daily energy-saving behaviour: evidence from Germany, the Netherlands and Belgium. *International Economics and Economic Policy*, *14*(3), 481–499. https://doi.org/10.1007/s10368-017-0381-7

UNFCCC. Conference of the Parties (COP). (2015). *Paris Climate Change Conference-November 2015, COP 21*. *United Nations*. Retrieved from http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

United Nations. (2004). World Population To 2300. *Economic & Social Affairs*, *18*(3), 553–561. https://doi.org/10.1016/j.asieco.2007.02.015

Vringer, K., & Dassen, T. (2016). *De Slimme Meter , Uitgelezen Energie(k)? Den Haag: PBL*. Retrieved from http://www.pbl.nl/sites/default/files/cms/publicaties/PBL-2016-de-slimme-meter-uitgelezen-energiek-2122.pdf

Wang, Z., Zhang, B., Yin, J., & Zhang, Y. (2011). Determinants and policy implications for household electricity-saving behaviour : Evidence from Beijing , China. *Energy Policy*, *39*(6), 3550–3557. https://doi.org/10.1016/j.enpol.2011.03.055

Wurtz, F., & Delinchant, B. (2017). "Smart buildings" integrated in "smart grids": A key challenge for the energy transition by using physical models and optimization with a "human-in-the-loop" approach. *Comptes Rendus Physique*, *1*, 1–17. https://doi.org/10.1016/j.crhy.2017.09.007

Yue, T., Long, R., & Chen, H. (2013). Factors influencing energy-saving behavior of urban households in jiangsu province. *Energy Policy*, *62*, 665–675. https://doi.org/10.1016/j.enpol.2013.07.051

Zafar, R., Mahmood, A., Razzaq, S., Ali, W., Naeem, U., & Shehzad, K. (2017). Prosumer based energy management and sharing in smart grid. *Renewable and Sustainable Energy Reviews*, *82*(1), 1675–1684. https://doi.org/10.1016/j.rser.2017.07.018

Zografakis, N., Sifaki, E., Pagalou, M., Nikitaki, G., Psarakis, V., & Tsagarakis, K. P. (2010). Assessment of public acceptance and willingness to pay for renewable energy sources in Crete, *14*, 1088–1095. https://doi.org/10.1016/j.rser.2009.11.009

APPENDIX I: Financial analyses

Curve Electricity	Unit	Start price													
		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Bare energy costs	[euro]	€ 0.170	€ 0.175	€ 0.181	€ 0.187	€ 0.194	€ 0.199	€ 0.205	€ 0.211	€ 0.216	€ 0.221	€ 0.227	€ 0.231	€ 0.235	€ 0.238
	[Relative increase in %]	2.00%	3.00%	3.00%	3.50%	3.50%	3.00%	3.00%	2.50%	2.50%	2.50%	2.50%	2.00%	1.50%	1.50%
Energy tax	[euro]	€ 0.053	€ 0.054	€ 0.056	€ 0.057	€ 0.058	€ 0.059	€ 0.061	€ 0.062	€ 0.063	€ 0.064	€ 0.066	€ 0.067	€ 0.068	€ 0.070
	[Relative increase in %]	8.00%	3.00%	3.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Sustainable energy storage	[euro]	€ 0.018	€ 0.021	€ 0.024	€ 0.024	€ 0.025	€ 0.025	€ 0.026	€ 0.026	€ 0.027	€ 0.027	€ 0.028	€ 0.028	€ 0.029	€ 0.030
	[Relative increase in %]	46.00%	15.00%	15.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Total	**[euro]**	**€ 0.241**	**€ 0.250**	**€ 0.260**	**€ 0.268**	**€ 0.277**	**€ 0.284**	**€ 0.292**	**€ 0.299**	**€ 0.306**	**€ 0.313**	**€ 0.320**	**€ 0.327**	**€ 0.332**	**€ 0.337**
	[Relative increase in %]	**6.00%**	**4.00%**	**4.00%**	**3.00%**	**3.00%**	**3.00%**	**3.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**

1.1 Energy price expectations

2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
€ 0.241	€ 0.241	€ 0.236	€ 0.231	€ 0.224	€ 0.217	€ 0.207	€ 0.196	€ 0.184	€ 0.175	€ 0.168	€ 0.163	€ 0.158	€ 0.155	€ 0.154	€ 0.154	€ 0.154
1.00%	0.00%	-2.00%	-2.00%	-3.00%	-3.00%	-5.00%	-5.00%	-6.00%	-5.00%	-4.00%	-3.00%	-3.00%	-2.00%	-1.00%	0.00%	0.00%
€ 0.071	€ 0.072	€ 0.074	€ 0.075	€ 0.077	€ 0.078	€ 0.080	€ 0.082	€ 0.083	€ 0.085	€ 0.087	€ 0.088	€ 0.090	€ 0.092	€ 0.094	€ 0.096	€ 0.097
2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
€ 0.030	€ 0.031	€ 0.031	€ 0.032	€ 0.033	€ 0.033	€ 0.034	€ 0.035	€ 0.035	€ 0.036	€ 0.037	€ 0.038	€ 0.038	€ 0.039	€ 0.040	€ 0.041	€ 0.041
2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
€ 0.342	**€ 0.344**	**€ 0.341**	**€ 0.338**	**€ 0.334**	**€ 0.329**	**€ 0.320**	**€ 0.312**	**€ 0.303**	**€ 0.296**	**€ 0.292**	**€ 0.289**	**€ 0.287**	**€ 0.286**	**€ 0.287**	**€ 0.290**	**€ 0.292**
1.00%	**1.00%**	**-1.00%**	**-1.00%**	**-1.00%**	**-1.00%**	**-3.00%**	**-3.00%**	**-3.00%**	**-2.00%**	**-2.00%**	**-1.00%**	**-1.00%**	**0.00%**	**0.00%**	**1.00%**	**1.00%**

Curve Gas	Unit	Start price																														
		2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**
Bare energy costs	[euro]	€ 0.256	€ 0.263	€ 0.269	€ 0.281	€ 0.292	€ 0.305	€ 0.317	€ 0.331	€ 0.345	€ 0.359	€ 0.374	€ 0.390	€ 0.406	€ 0.417	€ 0.427	€ 0.435	€ 0.444	€ 0.451	€ 0.458	€ 0.462	€ 0.467	€ 0.471	€ 0.476	€ 0.479	€ 0.481	€ 0.483	€ 0.486	€ 0.486	€ 0.486	€ 0.486	€ 0.486
	[Relative increase in %]	2.50%	2.50%	2.50%	4.20%	4.20%	4.20%	4.20%	4.20%	4.20%	4.20%	4.20%	4.20%	4.20%	2.50%	2.50%	2.00%	2.00%	1.50%	1.50%	1.00%	1.00%	1.00%	1.00%	0.50%	0.50%	0.50%	0.50%	0.00%	0.00%	0.00%	0.00%
Energy tax	[euro]	€ 0.260	€ 0.276	€ 0.292	€ 0.307	€ 0.319	€ 0.329	€ 0.338	€ 0.345	€ 0.352	€ 0.359	€ 0.366	€ 0.374	€ 0.381	€ 0.389	€ 0.397	€ 0.404	€ 0.413	€ 0.421	€ 0.429	€ 0.438	€ 0.447	€ 0.456	€ 0.465	€ 0.474	€ 0.483	€ 0.493	€ 0.503	€ 0.513	€ 0.523	€ 0.534	€ 0.544
	[Relative increase in %]	3.00%	6.00%	6.00%	5.00%	4.00%	3.00%	3.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Sustainable energy storage	[euro]	€ 0.029	€ 0.032	€ 0.035	€ 0.037	€ 0.039	€ 0.040	€ 0.041	€ 0.042	€ 0.043	€ 0.044	€ 0.044	€ 0.045	€ 0.046	€ 0.047	€ 0.048	€ 0.049	€ 0.050	€ 0.051	€ 0.052	€ 0.053	€ 0.054	€ 0.055	€ 0.056	€ 0.057	€ 0.059	€ 0.060	€ 0.061	€ 0.062	€ 0.063	€ 0.065	€ 0.066
	[Relative increase in %]	79.25%	11.00%	11.00%	6.00%	5.00%	3.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Total	**[euro]**	**€ 0.545**	**€ 0.570**	**€ 0.597**	**€ 0.625**	**€ 0.651**	**€ 0.674**	**€ 0.697**	**€ 0.718**	**€ 0.740**	**€ 0.762**	**€ 0.785**	**€ 0.809**	**€ 0.834**	**€ 0.852**	**€ 0.872**	**€ 0.889**	**€ 0.907**	**€ 0.923**	**€ 0.939**	**€ 0.953**	**€ 0.968**	**€ 0.982**	**€ 0.997**	**€ 1.010**	**€ 1.023**	**€ 1.036**	**€ 1.050**	**€ 1.061**	**€ 1.073**	**€ 1.084**	**€ 1.096**
	[Relative increase in %]	**5.10%**	**5.00%**	**5.00%**	**5.00%**	**4.00%**	**4.00%**	**3.00%**	**3.00%**	**3.00%**	**3.00%**	**3.00%**	**3.00%**	**3.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**2.00%**	**1.00%**	**1.00%**	**1.00%**	**1.00%**	**1.00%**	**1.00%**	**1.00%**	**1.00%**

Scenario 1: EPC 0.4

Energy demand EPC 0.4

1.A. ENERGY DEMAND	Unit	2018 'salderen'	2020 'feed-in fee'
Gas m3 space heating	[m3/year]	396.89	396.89
Gas m3 hot tap water	[m3/year]	288.41	288.41
Total gas demand	**[m3/year]**	**685.30**	**685.30**
Electricity space heating	[kWh/year]	-	-
Electricity hot tap water	[kWh/year]	-	-
Electricity cooling / summer comfort	[kWh/year]	378.00	378.00
Auxiliary energy - fan, pump, parasitic lighting	[kWh/year]	585.00	585.00
Equipment - electrically not building-related	[kWh/year]	2,985.00	2,985.00
PV installation total	[kWh/year]	-3,740.00	-3,740.00
PV installation indirect usage (feed-in fee)	[kWh/year]	-	2,618.00
Total electricity demand	**[kWh/year]**	**208**	**2,826**

Gross margin EPC 0.4

1.B. ENERGY PURCHASE	Unit	2018 'salderen'	2020 'feed-in fee'
Energy costs			
Bare energy costs (electricity)	[euro/year]	€ 35.43	€ 510.70
Energy tax (electricity)	[euro/year]	€ 10.97	€ 158.12
Sustainable energy storage (electricity)	[euro/year]	€ 3.74	€ 67.27
Total electricity	**[euro/year]**	**€ 50.14**	**€ 736.09**
Gas commodity	[euro/year]	€ 175.66	€ 184.56
Energy tax (gas)	[euro/year]	€ 178.19	€ 200.21
Sustainable energy storage (gas)	[euro/year]	€ 19.53	€ 24.06
Total Gas	[euro/year]	€ 373.38	€ 408.83
Total purchasing costs	**[euro/year]**	**€ 423.53**	**€ 1,144.92**
Revenues			
Feed-in fee	[euro/year]	-	€ 410.50
Gross margin	**[kWh/year]**	**€ -423.53**	**€ -734.42**

Operating expenses EPC 0.4

1.C. OPERATING EXPENSES	Unit	2018
Maintenance		
Gas boiler	[euro/year]	€ 100.00
Cooling machine	[euro/year]	€ 120.00
Inverter	[euro/year]	€ -
PV panels	[euro/year]	€ 50.00
Network operator costs		
Electricity network	[euro/year]	€ 154.71

Gas network	[euro/year]	€ 118.14
Total operating expenses	[euro/year]	€ 542.85

Investment costs EPC 0.4

1.D. INVESTMENTS	Unit	2018
Initial investment (gas boiler)	[euro/year]	€ 3,150.00
Initial investment (cooling machine)	[euro/year]	€ 1,250.00
Initial investment (inverter)	[euro/year]	€ 680.00
Initial investment (PV panels)	[euro/year]	€ 4,000.00
Total initial investment	**[euro/year]**	**€ 9,080.00**

Scenario 2: BENG

Energy demand BENG

1.A. ENERGY DEMAND	Unit	2018 'salderen'	2020 'feed-in fee'
Gas m3 space heating	[m3/year]	-	-
Gas m3 hot tap water	[m3/year]	-	-
Total gas demand	**[m3/year]**	**-**	**-**
Electricity space heating	[kWh/year]	696.67	696.67
Electricity hot tap water	[kWh/year]	810.00	810.00
Electricity cooling / summer comfort	[kWh/year]	56.70	56.70
Auxiliary energy - fan, pump, parasitic lighting	[kWh/year]	585.00	585.00
Equipment - electrically not building-related	[kWh/year]	2,985.00	2,985.00
PV installation total	[kWh/year]	-3,740.00	-3,740.00
PV installation indirect usage	[kWh/year]	-	2,618.00
Total electricity demand	**[kWh/year]**	**1,393**	**4,011**

Gross margin BENG

1.B. ENERGY PURCHASE	Unit	2018 'salderen'	2020 'feed-in fee'
Energy costs			
Bare energy costs (electricity)	[euro/year]	€ 237.35	€ 724.91
Energy tax (electricity)	[euro/year]	€ 73.49	€ 224.44
Sustainable energy storage (electricity)	[euro/year]	€ 25.08	€ 95.49
Total electricity	**[euro/year]**	**€ 335.91**	**€ 1,044.84**
Gas commodity	[euro/year]	€ -	€ -
Energy tax (gas)	[euro/year]	€ -	€ -
Sustainable energy storage (gas)	[euro/year]	€ -	€ -
Total Gas	[euro/year]	€ -	€ -
Total purchasing costs	**[euro/year]**	**€ 335.91**	**€ 1,044.84**
Revenues			
Feed-in fee	[euro/year]	-	€ 410.50

Gross margin	**[kWh/year]**	**€ -335.91**	**€ -634.34**

Operating expenses BENG

1.C. OPERATING EXPENSES	Unit	2018
Maintenance		
Heat pump	[euro/year]	€ 110.00
Individual borehole	[euro/year]	-
Inverter	[euro/year]	-
PV panels	[euro/year]	€ 50.00
Network operator costs		
Electricity network	[euro/year]	€ 154.71
Gas network	[euro/year]	-
Total operating expenses	**[euro/year]**	**€ 314.71**

Investment costs BENG

1.D. INVESTMENTS	Unit	2018
Initial investment (heat pump)	[euro/year]	€ 5,500.00
Initial investment (individual borehole)	[euro/year]	€ 12,000.00
Initial investment (inverter)	[euro/year]	€ 680.00
Initial investment (PV panels)	[euro/year]	€ 4,000.00
Total initial investment	**[euro/year]**	**€ 22,180.00**

Scenario 3: Prosumer

Energy demand Prosumer

1.A. ENERGY DEMAND	Unit	2018 'salderen'	2020 'feed-in fee'
Gas m3 space heating	[m3/year]	-	-
Aardgas m3 hot tap water	[m3/year]	-	-
Total gas demand	**[m3/year]**	**-**	**-**
Electricity space heating	[kWh/year]	696.67	696.67
Electricity hot tap water	[kWh/year]	810.00	810.00
Electricity cooling / summer comfort	[kWh/year]	56.70	56.70
Auxiliary energy - fan, pump, parasitic lighting	[kWh/year]	585.00	585.00
Equipment - electrically not building-related	[kWh/year]	2,985.00	2,985.00
PV installation total	[kWh/year]	-3,740.00	-3,740.00
PV installation – own usage	[kWh/year]	-1,122.00	-1,122.00
PV installation – in-home battery	[kWh/year]	-2,618.00	-2,618.00
In-home battery electricity usage	[kWh/year]	183.26	183.26
In-home battery – own usage	[kWh/year]	-2,094.40	-2,094.40
In-home battery – purchase community	[kWh/year]	-523.60	-523.60
Total electricity demand	**[kWh/year]**	**2,100**	**2,100**

Gross margin Prosumer

1.B. ENERGY PURCHASE	Unit	2018 'salderen'	2020 'feed-in fee'
Energy costs			
Bare energy costs (electricity)	[euro/year]	€ 357.75	€ 379.54
Energy tax (electricity)	[euro/year]	€ 110.77	€ 117.51
Sustainable energy storage (electricity)	[euro/year]	€ 37.80	€ 50.00
Total electricity	**[euro/year]**	**€ 506.32**	**€ 547.05**
Gas commodity	[euro/year]	€ -	€ -
Energy tax (gas)	[euro/year]	€ -	€ -
Sustainable energy storage (gas)	[euro/year]	€ -	€ -
Total Gas	[euro/year]	€ -	€ -
Total purchasing costs	**[euro/year]**	**€ 506.32**	**€ 547.05**
Revenues			
Energy purchase community	[euro/year]	€ 100.98	€ 109.11
Gross margin	**[kWh/year]**	€ -405.34	€ -437.94

Operating expenses Prosumer

1.C. OPERATING EXPENSES	Unit	2018
Maintenance		
Heat pump	[euro/year]	€ 110.00
Individual borehole	[euro/year]	-
Inverter	[euro/year]	-
PV panels	[euro/year]	€ 50.00
In-home battery	[euro/year]	-
Network operator costs		
Electricity network	[euro/year]	€ 154.71
Gas network	[euro/year]	-
Total operating expenses	**[euro/year]**	**€ 314.71**

Investment costs Prosumer

1.D. INVESTMENTS	Unit	2018
Initial investment (heat pump)	[euro/year]	€ 5,500.00
Initial investment (individual borehole)	[euro/year]	€ 12,000.00
Initial investment (inverter)	[euro/year]	€ 680.00
Initial investment (PV panels)	[euro/year]	€ 4,000.00
Initial investment (in-home battery)	[euro/year]	€ 5,000.00
Initial investment (ICT software)	[euro/year]	€ 1,000.00
Total initial investment	**[euro/year]**	**€ 28,180.00**

Cashflow scenarios

CASHFLOW SCENARIOS	TOTAL	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
		0	1	2	3	4	5	6	7	8	9	10	11
Scenarios		**2018**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
EPC 0.4													
Cashflow	[euro/year]	€ -9,080	€ -966	€ -996	€ -1,299	€ -1,352	€ -1,404	€ -1,453	€ -1,503	€ -1,549	€ -1,596	€ -1,644	€ -1,771
Cashflow cum.	[euro/year]	€ -9,080	€ -8,114	€ -7,117	€ -5,818	€ -4,466	€ -3,061	€ -1,608	€ -106	€ -1,443	€ 3,039	€ 4,684	€ 6,454
BENG													
Cashflow	[euro/year]	€ -22,180	€ -651	€ -670	€ -962	€ -1,000	€ -1,040	€ -1,076	€ -1,114	€ -1,149)	€ -1,184	€ -1,220	€ -1,334
Cashflow cum.	[euro/year]	€ -22,180	€ -21,529	€ -20,859	€ -19,898	€ -18,898	€ -17,858	€ -16,782	€ -15,668	€ -14,519)	€ -13,335	€ -12,115	€ -10,780
PROSUMER													
Cashflow	[euro/year]	€ -28,180	€ -720	€ -742	€ -765	€ -785	€ -806	€ -825	€ -845	€ -863)	€ -883	€ -902	€ -1,032
Cashflow cum.	[euro/year]	€ -28,180	€ -27,460	€ -26,718	€ -25,952	€ -25,167	€ -24,362	€ -23,537	€ -22,692	€ -21,828)	€ -20,946	€ -20,044	€ -19,011
SCENARIO COMPARISON													
BENG - EPC 0.4	[euro/year]	€ -13,100	€ 316	€ 326	€ 337	€ 352	€ 365	€ 377	€ 389	€ 400	€ 412	€ 424	€ 437
BENG - EPC 0.4 cum.	[euro/year]	€ -13,100	€ -12,784	€ -12,458	€ -12,120	€ -11,768	€ -11,403	€ -11,027	€ -10,638	€ -10,238	€ -9,826	€ -9,402	€ -8,965
Prosumer - EPC 0.4	[euro/year]	€ -19,100	€ 246	€ 254	€ 534	€ 567	€ 599	€ 628	€ 658	€ 685	€ 713	€ 742	€ 739
Prosumer - EPC 0.4 cum.	[euro/year]	€ -19,100	€ -18,854	€ -18,599	€ -18,066	€ -17,499	€ -16,900	€ -16,272	€ -15,614	€ -14,929	€ -14,215	€ -13,473	€ -12,734
Prosumer - BENG	[euro/year]	€ -6,000	€ -69	€ -72	€ 196	€ 215	€ 234	€ 251	€ 269	€ 285	€ 302	€ 318	€ 302
Prosumer - BENG cum.	[euro/year]	€ -6,000	€ -6,069	€ -6,142	€ -5,945	€ -5,730	€ -5,496	€ -5,245	€ -4,976	€ -4,691	€ -4,389	€ -4,071	€ -3,769

Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
12	13	14	15	16	17	18	19	20	21	22	23	24	25
2029	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**
€ -1,819	€ -1,866	€ -1,908	€ -1,948	€ (8,818)	€ (1,999)	€ (2,017)	€ (2,030)	€ (2,042)	€ (2,119)	€ (2,120)	€ (2,118)	€ (2,123)	€ (1,819)
€ 8,274	€ 10,140	€ 12,048	€ 13,996	€ 22,814	€ 24,813	€ 26,830	€ 28,860	€ 30,901	€ 33,020	€ 35,141	€ 37,259	€ 39,382	€ 8,274
€ -1,368	€ -1,398	€ -1,429	€ -1,455	€ (7,887)	€ (1,469)	€ (1,467)	€ (1,456)	€ (1,446)	€ (1,497)	€ (1,472)	€ (1,441)	€ (1,422)	€ (1,368)
€ -9,412	€ -8,014	€ -6,585	€ -5,130	€ 2,757	€ 4,226	€ 5,693	€ 7,148	€ 8,595	€ 10,091	€ 11,563	€ 13,004	€ 14,426	€ (9,412)
€ -1,053	€ -1,072	€ -1,091	€ -1,108	€ (12,535)	€ (1,123)	€ (1,126)	€ (1,126)	€ (1,125)	€ (1,228)	€ (1,218)	€ (1,205)	€ (1,199)	€ (1,053)
€ -17,958	€ -16,886	€ -15,796	€ -14,688	€ (2,152)	€ (1,029)	€ 97	€ 1,223	€ 2,348	€ 3,576	€ 4,794	€ 5,999	€ 7,197	€ (17,958)
€ 451	€ 467	€ 479	€ 493	€ 931	€ 530	€ 551	€ 574	€ 595	€ 622	€ 649	€ 677	€ 701	€ 722
€ -8,514	€ -8,047	€ -7,567	€ -7,074	€ -6,144	€ -5,613	€ -5,063	€ -4,489	€ -3,893	€ -3,271	€ -2,622	€ -1,945	€ -1,245	€ -522
€ 766	€ 794	€ 817	€ 840	€ -3,718	€ 876	€ 891	€ 904	€ 916	€ 891	€ 903	€ 913	€ 924	€ 937
€ -11,968	€ -11,174	€ -10,357	€ -9,516	€ -13,234	€ -12,358	€ -11,467	€ -10,563	€ -9,647	€ -8,756	€ -7,853	€ -6,940	€ -6,015	€ -5,078
€ 315	€ 327	€ 338	€ 347	€ -4,649	€ 346	€ 340	€ 330	€ 321	€ 269	€ 254	€ 236	€ 224	€ 215
€ -3,454	€ -3,127	€ -2,789	€ -2,442	€ -7,090	€ -6,745	€ -6,405	€ -6,074	€ -5,754	€ -5,485	€ -5,231	€ -4,995	€ -4,771	€ -4,556

APPENDIX II: Questionnaire

TU/e Technische Universiteit Eindhoven University of Technology

Collectief Energie Initiatief

SWECO

Page: Pagina 1 Introductie

Beste,

Mijn naam is Luc de Vet en voor het afronden van mijn master thesis op de Technische Universiteit Eindhoven heb ik een enquête opgesteld.

Het onderzoek richt zich op de bereidheid van mensen om te participeren in een collectief energie-initiatief waarbij wijkbewoners samen energie opwekken. Dit onderzoek wordt uitgevoerd in samenwerking met ingenieurs- en adviesbureau Sweco.

Om aan deze enquête deel te nemen hoeft u geen kennis te hebben over collectieve energie initiatieven. Gedurende de enquête informeren wij u hierover.

Deze enquête duurt +- 10 minuten. Alle antwoorden worden vertrouwelijk verwerkt en zijn volledig anoniem.

Ik wil u alvast hartelijk bedanken voor het openen en verder invullen van deze enquête!

Mocht u vragen hebben of meer willen weten van mijn onderzoek, dan kunt u mij altijd bereiken op: lucdvet@gmail.com

Volgende

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Page: Pagina 2

Wat is uw geslacht?

- ○ Man
- ○ Vrouw

Wat is uw leeftijd?

____

Wat is uw hoogst genoten opleiding?

- ○ Basisschool / Lagere school
- ○ Voorbereidend middelbaar beroepsonderwijs (v(m)bo, lts, lbo, huishoudschool)
- ○ Middelbaar algemeen voortgezet onderwijs (mavo, (m)ulo)
- ○ Middelbaar beroepsonderwijs (mbo, mts)
- ○ Hoger algemeen en voorbereidend wetenschappelijk onderwijs (havo, vwo, hbs)
- ○ Hoger beroepsonderwijs (hbo, pabo, hts, heao)
- ○ Wetenschappelijk onderwijs (universiteit, gepromoveerd)
- ○ Anders, namelijk:

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Page: Pagina 3

Wat is de samenstelling van uw huishouden?

- ○ 1-persoonshuishouden
- ○ 2-persoonshuishouden
- ○ 3-persoonshuishouden
- ○ 4-persoonshuishouden
- ○ >4-persoonshuishouden
- ○ Gedeelde woning (bv. studentenhuis)

Hoeveel kinderen maken deel uit van dit huishouden?

Wat is uw jaarlijks persoonlijk bruto inkomen

- ○ 0 tot en met 15000 euro
- ○ 15001 euro tot en met 25000 euro
- ○ 25001 euro tot en met 35000 euro
- ○ 35001 euro tot en met 45000 euro
- ○ 45001 euro tot en met 55000 euro
- ○ >55000 euro
- ○ Dat weet ik niet/zeg ik liever niet

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Collectief Energie Initiatief

Page: Pagina 4

Wat is uw postcode?

bijv 5600 | bijv AA

In wat voor type woning woont u?

- ○ Vrijstaande woning
- ○ 2-onder-1 kap
- ○ Rijtjeswoning hoek
- ◉ Rijtjeswoning tussen
- ○ Galerijwoning
- ○ Appartement
- ○ Overige

Wat is de huidige eigendomssituatie van uw woning

- ○ Eigenaar
- ◉ Huurder
- ○ Anders, namelijk

Zijn uw energiekosten opgenomen in uw huur?

- ○ Huur (incl. energiekosten)
- ○ Huur (excl. energiekosten)

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Collectief Energie Initiatief

Page: Pagina 5

Wat voor energiebesparende maatregelen heeft u al toegepast in uw woning? (meerdere keuzes mogelijk)

- ☐ Geen
- ☐ Warmtepomp
- ☐ Zonnepanelen
- ☐ Zonnecollector
- ☐ Anders, namelijk

Welk karakter heeft uw buurt?

- ○ Centrum-stedelijk
- ○ Buiten-centrum stad
- ○ Centrum-dorps
- ○ Landelijk

Hoe volgt u de technologische trends?

- ○ Ik heb altijd de nieuwste gadgets
- ○ Ik heb de nieuwste gadgets altijd vrij snel
- ○ Ik ga mee met de tijd op technologisch gebied
- ○ Ik schaf technologie aan twee modellen later aan
- ○ Ik ga niet mee met technologische trends

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Collectief Energie Initiatief

Page: Pagina 6

De enquête wordt nu vervolgd met een keuze-experiment. Stel:

Er is een initiatief in uw wijk om samen te werken met als doel om de energiekosten te verlagen. Het plan is om een collectief energie-initiatief te realiseren, waarin u niet alleen energie verbruikt, maar ook energie produceert op basis van hernieuwbare energiebronnen. Het is de bedoeling dat u er nu vanuit gaat dat u eigenaar bent van uw woning en dat u er nog minimaal 20 jaar blijft wonen.

In de volgende 9 vragen wordt u gevraagd om te kiezen tussen twee situaties. Deze situaties betreffen steeds een andere manier van energie opwekken en besparen. Maar ook wat betreft de financiering is er een verschil:

- Eigen initiatief: u neemt deel aan een collectief energie-initiatief en u financiert dit zelf. Dit levert u per jaar ruime financiële voordelen op.
- Uitbesteden: u neemt deel aan een collectief energie initiatief, maar u besteedt de financiering uit aan een extern bedrijf (een zogenaamde ESCO). Wanneer uw contract met dit externe bedrijf is verlopen, zijn de middelen (bijvoorbeeld de zonnepanelen) van u. U kunt hierme nog een aantal jaren energie opwekken/besparen.

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Collectief Energie Initiatief

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Page: Pagina 8

Voordat het keuze experiment start, worden hieronder de kenmerken van de situaties uitgelegd:

Financiële consequenties: Om energie op te wekken en te besparen kunnen verschillende technologieën gebruikt worden. In dit onderzoek gaan we uit van:

- Zonnepanelen: paneel dat zonne-energie omzet in elektriciteit.
- Warmte-koudeopslag: methode om energie in de vorm van warmte of koude op te slaan in de bodem. De techniek wordt gebruikt om gebouwen te verwarmen en/of te koelen.
- Thuisaccu: maakt het mogelijk om energie uit uw zonnepanelen op te slaan slaan en later te gebruiken.
  Zowel de kosten als de besparingen worden weergegeven, alsmede de terugverdientijd en contractduur.

Wijkdeelname: het percentage van de inwoners van uw wijk dat deel neemt aan het collectief energie-initiatief.

Aansturing van huishoudelijke apparaten:

- Zelf bepalen: U bepaalt zelf wanneer u uw wasmachine en andere huishoudelijke apparaten aan zet. U heeft veel flexibiliteit, maar u bent zelf verantwoordelijk voor het tijdstip van energieverbruik. (Het is goedkoper om elektriciteit te verbruiken op het moment dat er veel wordt opgewekt).
- Semi-automatisch: U geeft een uiterlijke tijd aan op uw wasmachine en andere huishoudelijke apparaten wanneer deze klaar moeten zijn. Een energie-systeem bepaalt wanneer deze aan gaan op basis van de hoeveelheid in de buurt opgewekte hernieuwbare energie. Dit is meestal tussen 11.00 en 15.00 uur. U heeft minder flexibiliteit, maar u behaalt wel financiële voordelen.
- Automatisch: Het energie-systeem bepaalt voor u wanneer uw wasmachine en andere huishoudelijke apparaten aan gaan (indien nodig). Dit gebeurt op basis van de hoeveelheid in de wijk opgewekte hernieuwbare energie (meestal tussen 11.00 en 15.00). U heeft een matige flexibiliteit, maar u behaalt wel aanzienlijke financiële besparingen.

Organisatorische rol: de mate waarin u een verantwoordelijkheid wilt nemen in het opzetten van het collectief energie initiatief.

- Actieve rol: u participeert in het initiatief en u neemt een redelijke organisatorische verantwoordelijkheid. U bent sturend in het opzetten van een collectief energie initiatief.
- Beperkte verantwoordelijkheid: u participeert in het initiatief en u neemt een beperkte verantwoordelijkheid door bijvoorbeeld deel te nemen aan de ledenvergaderingen.
- Passieve rol: u participeert in het initiatief, maar u neemt geen organisatorische verantwoordelijkheid.

Hierna vragen we u 9 keer een keuze te maken tussen twee verschillende situaties. Echter, het kan voorkomen dat u geen van beide situaties acceptabel vindt. Dan kunt u voor "Geen van beide" kiezen.

Vorige | Volgende

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Collectief Energie Initiatief

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Page: Stated Choice Experiment

U krijgt 9 keer een keuzeset voorgelegd, waarbij steeds factoren veranderen. Maakt u deze alstublieft af.

Kenmerken	Eigen initiatief	Uitbesteden	Geen van beide
Financiële consequenties - Investering - Besparing per jaar	Zonnepanelen en warmte-koude opslag €18.500 investering €1.200 besparing per jaar 13 jaar terugverdientijd	Zonnepanelen Investering door ESCO €100 besparing per jaar 7 jaar contract	
Wijkdeelname	50% deelname	25% deelname	
Aansturing huishoudelijke apparaten	Zelf bepalen	Semi-automatisch	
Organisatorische deelname	Beperkte verantwoordelijkheid (2 uur / maand)	Passieve rol (0-1 uur / maand)	
UW KEUZE:	○	○	○

Welk(e) aspect(en) waren bij 'financiële consequenties' van invloed op uw keuze? (meerdere mogelijkheden)

- ☐ Het investeringsbedrag voor zonnepanelen, WKO, etc.
- ☐ Financiële voordelen per jaar
- ☐ Terugverdientijd / contract periode
- ☐ Geen van de bovenstaande

Vorige | Volgende

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Collectief Energie Initiatief

SWECO

Page: Pagina 9

In welke mate bent u het met de volgende stellingen eens?

	Volledig oneens	Oneens	Neutraal	Eens	Volledig eens
Ik maak me zorgen over de opwarming van de aarde.	○	○	○	○	○
De meerderheid van de bevolking handelt niet milieubewust.	○	○	○	○	○
Ik ben bereid meer te betalen voor milieuvriendelijke middelen.	○	○	○	○	○
De overheid zou meer moeten ondernemen om het klimaatprobleem aan te pakken.	○	○	○	○	○
Ik zou graag onafhankelijker willen zijn van grote energie-aanbieders.	○	○	○	○	○
Ik ben bereid om een milieuvriendelijker energiegedrag aan te nemen.	○	○	○	○	○
Ik zou graag worden gezien met zonnepanelen op mijn huis.	○	○	○	○	○
Ik ben bereid om deel te nemen aan een collectief energie-initiatief	○	○	○	○	○

Ik wil u hartelijk bedanken voor het invullen van deze enquête! Klik op volgende om de enquete af te sluiten.

Vorige | Volgende

APPENDIX III: Effect coding choice sets

Alternative	Attribute	Attribute level	Coding	Coding
Own initiative	Financial consequences	Solar panels	1	0
		Solar panels, BTES system	0	1
		Solar panels, BTES system, Battery	-1	-1
Own initiative	Community involvement	25% participation	1	0
		50% participation	0	1
		75% participation	-1	-1
Own initiative	Control of appliances	Own control	1	0
		Semi-automatic control	0	1
		Automatic control	-1	-1
Own initiative	Organizational participation	Active role	1	0
		Minor participation	0	1
		Passive role	-1	-1
Outsourcing	Financial consequences	Solar panels	1	0
		Solar panels, WKO	0	1
		Solar panels, WKO, Battery	-1	-1
Outsourcing	Community involvement	25% participation	1	0
		50% participation	0	1
		75% participation	-1	-1
Outsourcing	Control of appliances	Own control	1	0
		Semi-automatic control	0	1
		Automatic control	-1	-1
Outsourcing	Organizational participation	Active role	1	0
		Minor participation	0	1
		Passive role	-1	-1

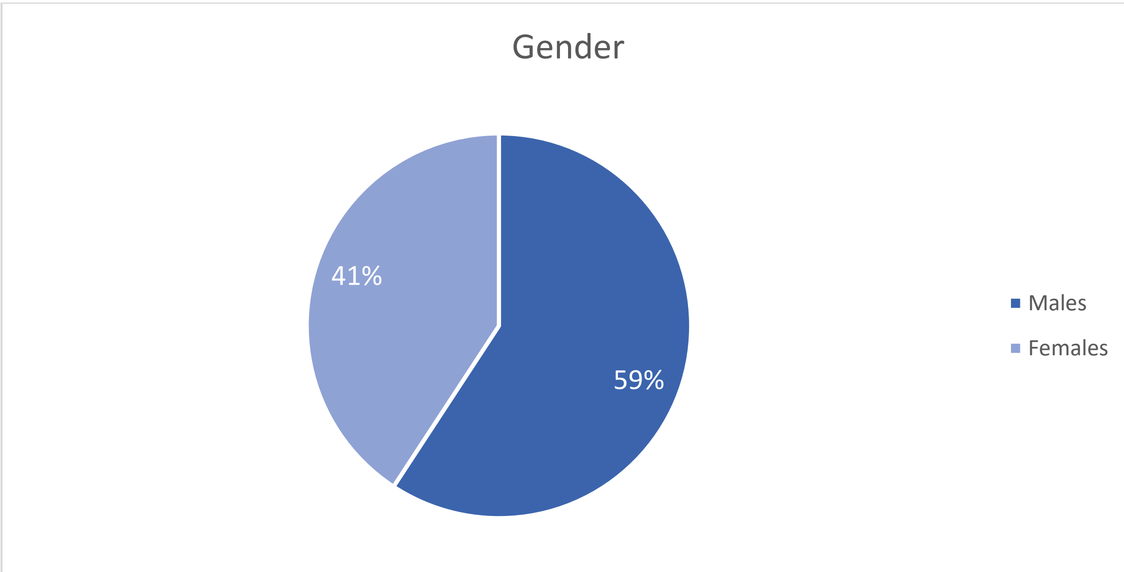
Effect coding of 27 choice sets

CS	Alt	X1		X2		X3		X4		X5		X6		X7		X8	
1	1	-1	-1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	0	1	-1	-1	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	-1	-1	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	-1	-1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	-1	-1	0	1	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	1	-1	-1	1	0	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	1	0	1	0	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	-1	-1	-1	-1	0	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	-1	-1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	-1	-1	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	-1	-1	0	1	-1	-1	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	1	0	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	-1	-1	0	1	-1	-1	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	-1	-1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	-1	-1	0	1	-1	-1	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	-1	-1	0	1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	1	-1	-1	0	1	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	1	0	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	0	-1	-1	0	1	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	1	0	0	1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	0	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	-1	-1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

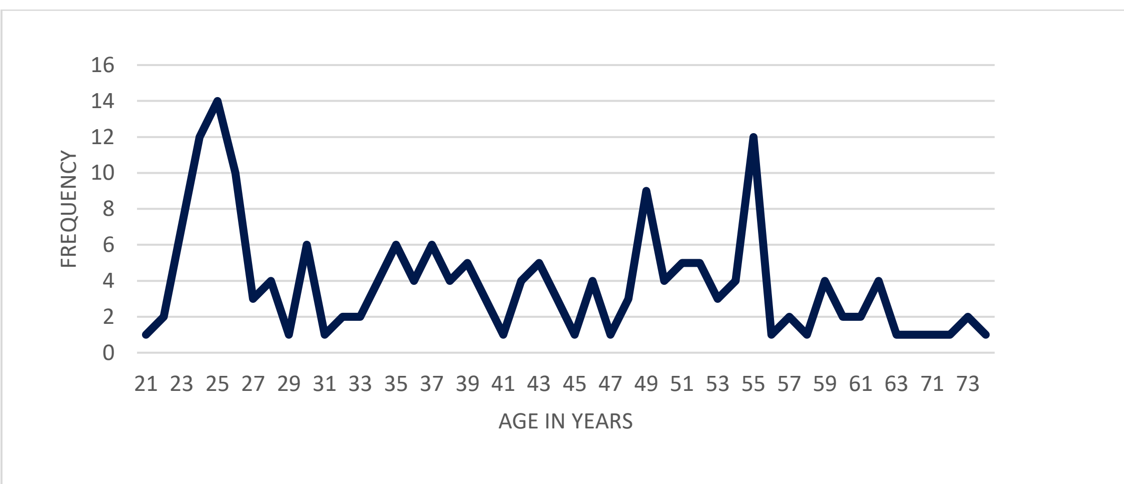
14	1	-1	-1	1	0	-1	-1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	0	1	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	1	-1	-1	0	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	-1	-1	1	0	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	-1	-1	0	1	-1	-1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	0	1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	-1	-1	0	1	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1	0	1	-1	-1	1	0	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	1	0	1	0	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	-1	-1	-1	-1	-1	-1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	1	0	1	0	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	1	-1	-1	1	0	1	0	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	-1	-1	-1	-1	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	1	0	1	0	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	1	1	0	0	1	1	0	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	-1	-1	0	1	-1	-1	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	1	1	0	1	0	1	0	-1	-1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1	0	1	-1	-1	-1	-1
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX IV: Descriptive analysis

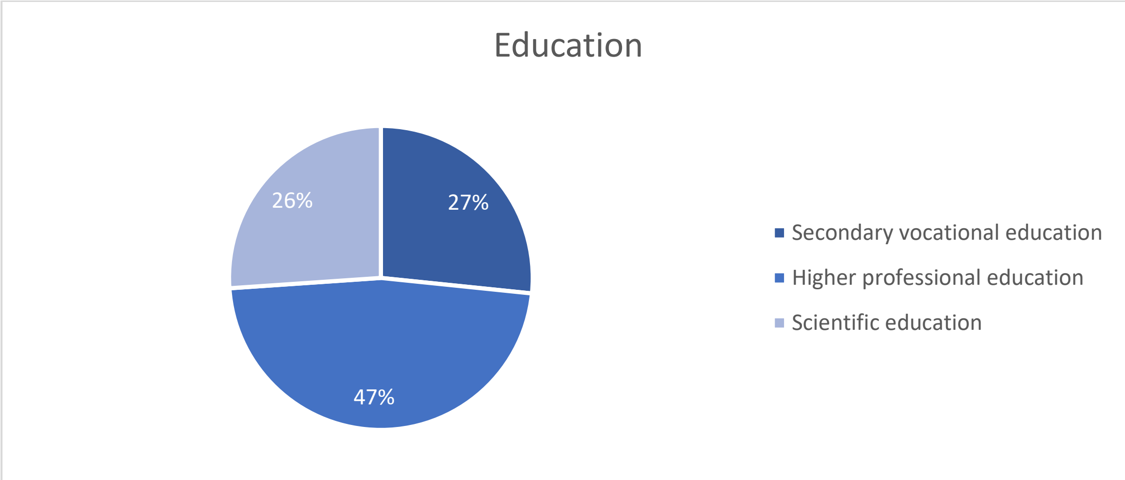
Gender:



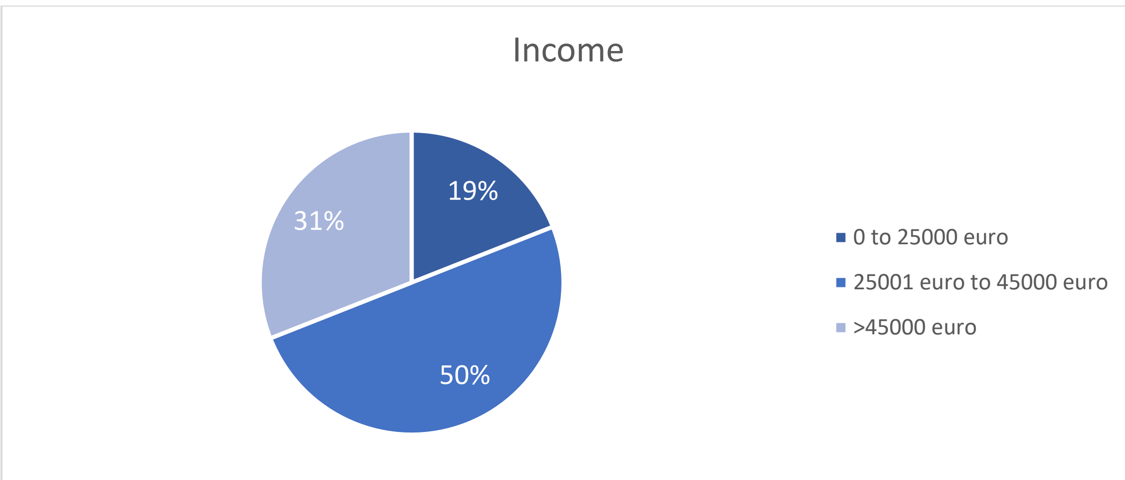
Age:



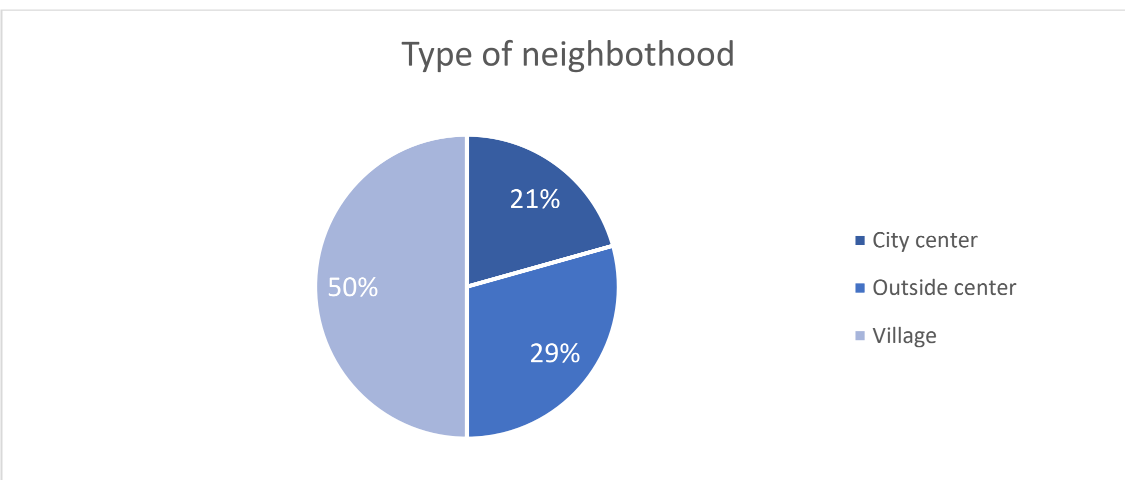
Education:



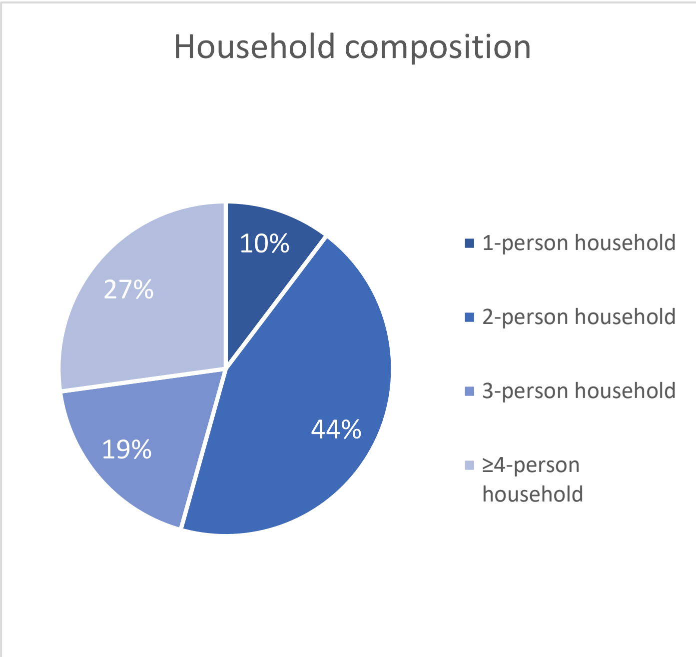
Income:



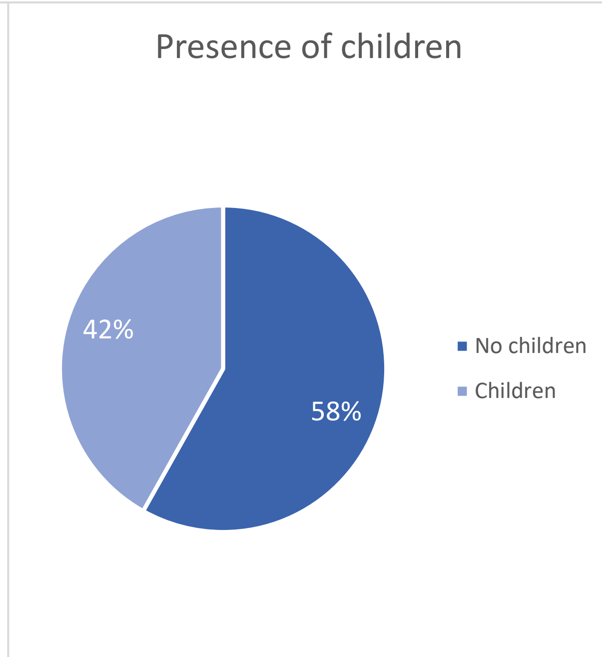
Type of neighborhood:



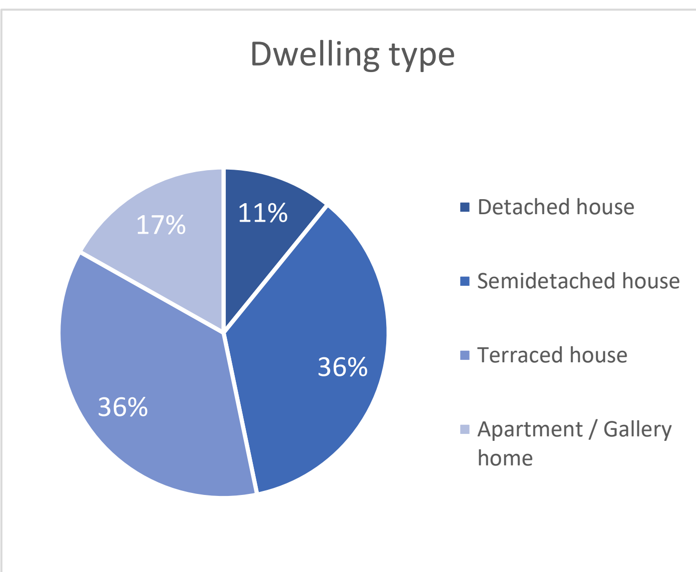
Household composition:



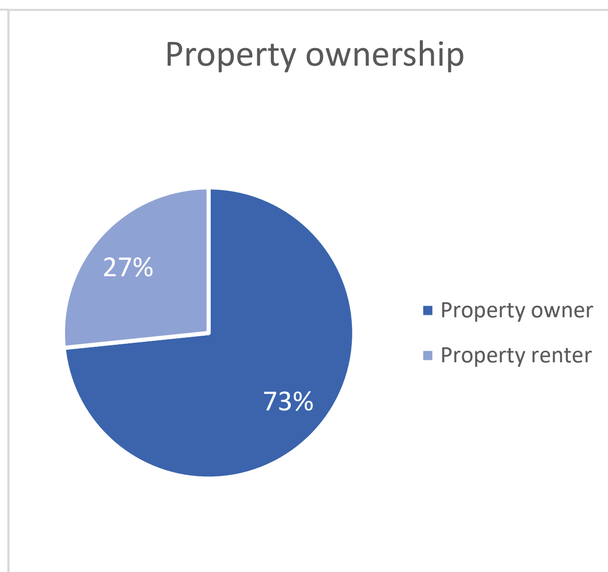
Presence of children:



Dwelling type:

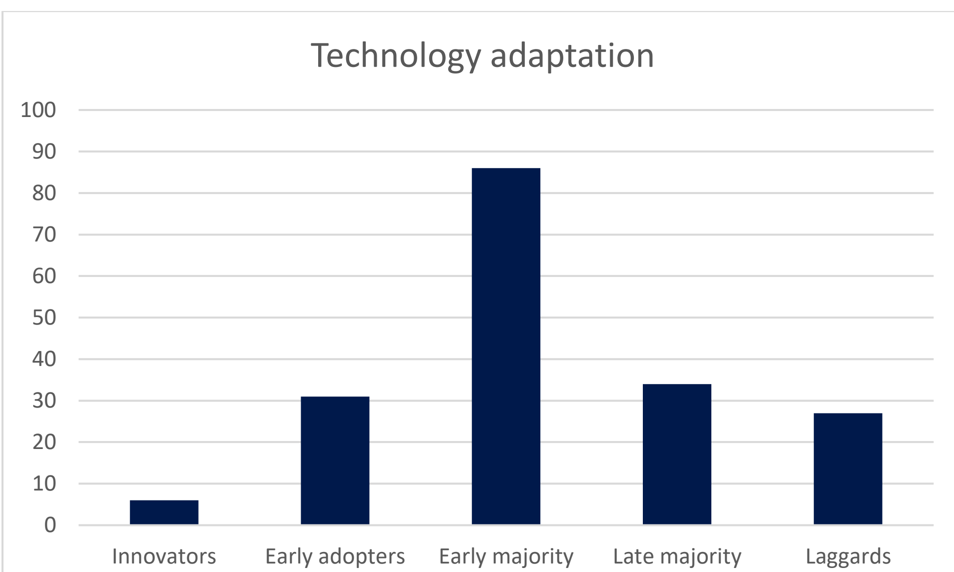


Property ownership:

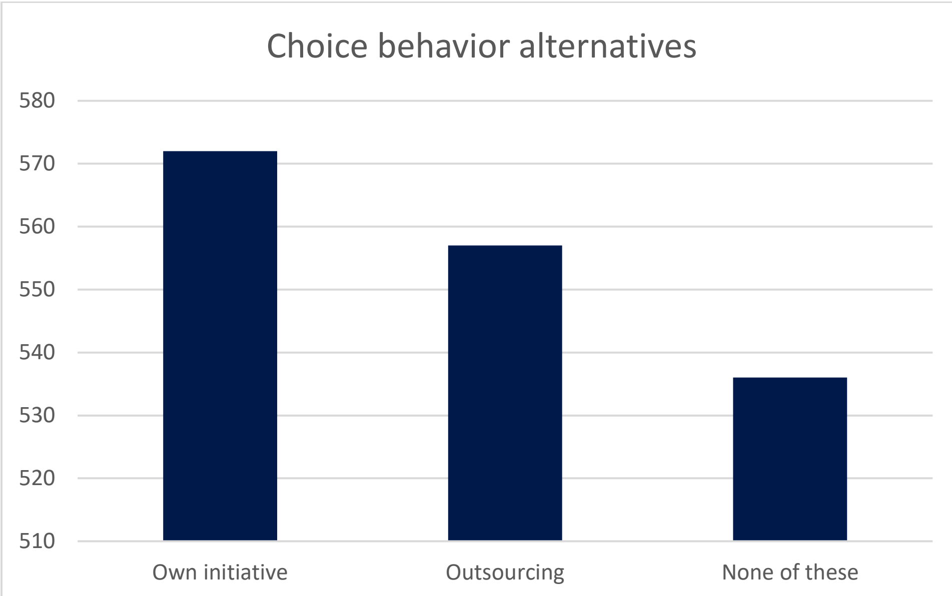


Geographical spread:

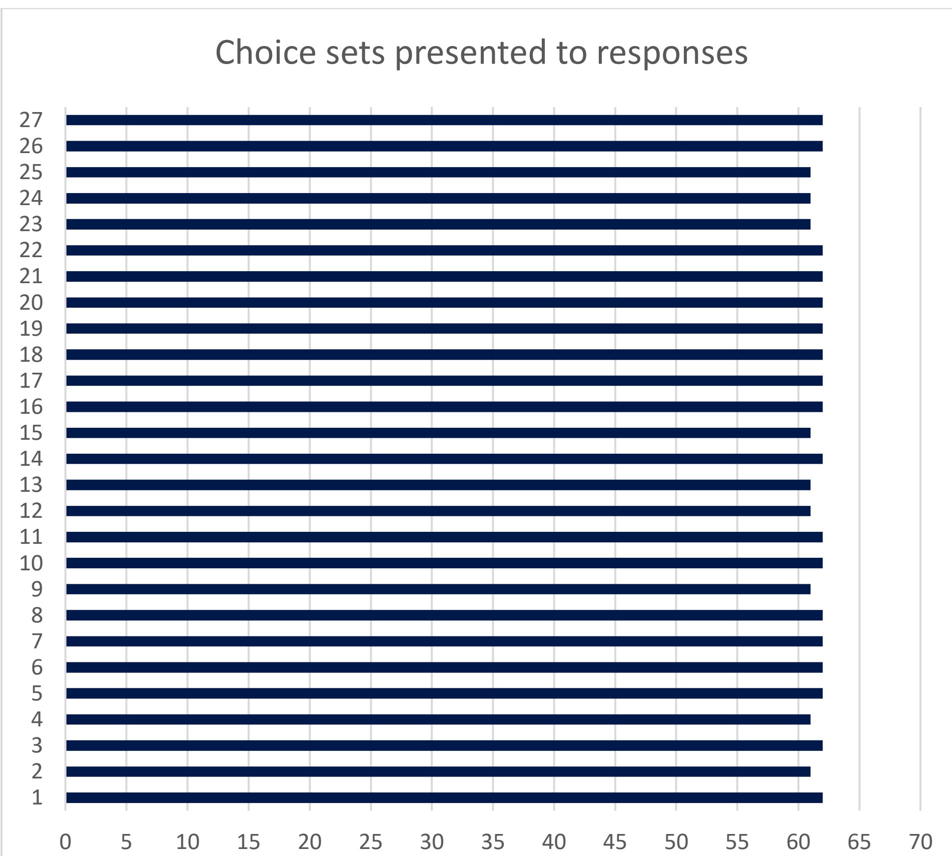
Technology adaptation:



Choice behavior alternatives:



Frequencies of choice sets presented to the respondents:



APPENDIX V: Chi-square representativeness sample

Gender

	Observed N	Expected N	Residual
Male	109	90.4	18.6
Female	75	93.6	-18.6
Total	184		

Test Statistics

	Gender
Chi-Square	7.555[a]
df	1
Asymp. Sig.	.006

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 90.4.

Age

	Observed N	Expected N	Residual
21 to 30 years	60	33.3	26.7
31 to 50 years	72	67.2	4.8
51 to 74 years	52	83.4	-31.4
Total	184		

Test Statistics

	Age
Chi-Square	33.507[a]
Df	2
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 33.3.

Education

	Observed N	Expected N	Residual
Secondary vocational education (mbo, mts)	63	122.0	-59.0
Higher professional education (hbo, pabo, hts, heao)	73	39.0	34.0
Scientific education (university, promoted)	48	23.0	25.0
Total	184		

Test Statistics

	Education
Chi-Square	85.322[a]
df	2
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 23.0.

Income

	Observed N	Expected N	Residual
0 to 25000 euro	35	64.2	-29.2
25001 euro to 45000 euro	92	55.7	36.3
>45000 euro	57	64.2	-7.2
Total	184		

Test Statistics

	Income
Chi-Square	37.717[a]
df	2
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 55.7.

Household_composition

	Observed N	Expected N	Residual
1-person household	19	69.9	-50.9
2-person household	81	60.0	21.0
3-person household	34	21.9	12.1
4-person household'	50	32.2	17.8
Total	184		

Test Statistics

	Household_composition
Chi-Square	60.977[a]
df	3
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.9.

Children

	Observed N	Expected N	Residual
No Children	107	122.5	-15.5
Children	77	61.5	15.5
Total	184		

Test Statistics

	Children
Chi-Square	5.852[a]
df	1
Asymp. Sig.	.016

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 61.5.

TypeDwelling

	Observed N	Expected N	Residual
Detached house	20	42.3	-22.3
Semidetached house	66	36.0	30.0
Terraced house	67	78.1	-11.1
Apartment / Gallery home	31	27.6	3.4
Total	184		

Test Statistics

	TypeDwelling
Chi-Square	38.682[a]
Df	3
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 27.6.

Property_ownership

	Observed N	Expected N	Residual
Property owner	135	104.6	30.4
Property renter	49	79.4	-30.4
Total	184		

Test Statistics

	Property_ownership
Chi-Square	20.486[a]
df	1
Asymp. Sig.	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 79.4.

APPENDIX VI: Crosstabs statements

Statement 1: I am worried about global warming

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	9	17	83	109
		8.3%	15.6%	76.1%	100%
	Female	5	12	58	75
		6.7%	16.0%	77.3%	100%
Age	21 to 30 years	7	14	39	60
		11.7%	23.3%	65.0%	100.0%
	31 to 50 years	3	8	61	72
		4.2%	11.1%	84.7%	100.0%
	> 50 years	4	7	41	52
		7.7%	13.5%	76.6%	100.0%
Education	Secondary vocational education	3	12	48	63
		4.8%	19.0%	76.2%	100.0%
	Higher professional education	9	11	53	73
		12.3%	15.1%	72.6%	100.0%
	Scientific education	2	6	40	48
		4.2%	12.5%	83.3%	100.0%
Income	0 to 25000 euro	5	6	24	35
		14.3%	17.1%	68.6%	100.0%
	25001 to 45000 euro	3	18	71	92
		3.3%	19.6%	77.2%	100.0%
	> 45000 euro	6	5	46	57
		10.5%	8.8%	80.7%	100.0%
Children	No children	6	19	82	107
		5.6%	17.8%	76.6%	100.0%
	Children	8	10	59	77
		10.4%	13.0%	76.6%	100.0%
Type of neighborhood	City center	4	7	27	38
		10.5%	18.4%	71.1%	100.0%
	Outside center	2	6	46	54
		3.7%	11.1%	85.2%	100.0%
	Village	8	16	68	92
		8.7%	17.4%	73.9%	100.0%
Total	Count	14	29	141	184
	% within statement 1	7.6%	15.8%	76.6%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	.160	2	.923
Age	12.070	6	.113
Education	4.771	4	.312
Income	8.051	4	.090
Children	1.992	2	.369
Type of neighborhood	3.475	4	.482

Statement 2: The majority of the population is not acting environmentally conscious

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	7	16	86	109
		6.4%	14.7%	78.9%	100%
	Female	2	8	65	75
		2.7%	10.7%	86.7%	100%
Age	21 to 30 years	2	5	53	60
		3.3%	8.3%	88.3%	100.0%
	31 to 50 years	2	8	62	72
		2.8%	11.1%	86.1%	100.0%
	> 50 years	5	11	36	52
		9.6%	21.2%	69.2%	100.0%
Education	Secondary	4	12	47	63
	vocational education	6.3%	19.0%	74.6%	100.0%
	Higher professional	5	7	61	73
	education	6.8%	9.6%	83.6%	100.0%
	Scientific education	0	5	43	48
		0.0%	10.4%	89.6%	100.0%
Income	0 to 25000 euro	2	7	26	35
		5.7%	20.0%	74.3%	100.0%
	25001 to 45000 euro	3	8	81	92
		3.3%	8.7%	88.0%	100.0%
	> 45000 euro	4	9	44	57
		7.0%	15.8%	77.2%	100.0%
Children	No children	7	16	84	107
		6.5%	15.0%	78.5%	100.0%
	Children	2	8	67	77
		2.6%	10.8%	87.0%	100.0%
Type of neighborhood	City center	1	4	33	38
		2.6%	10.5%	86.8%	100.0%
	Outside center	3	7	44	54
		5.6%	13.0%	81.4%	100.0%
	Village	5	13	74	92
		5.4%	14.1%	80.4%	100.0%
Total	Count	9	24	151	184
	% within statement 2	4.9%	13.0%	82.1%%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	2.156	2	.340
Age	17.017	6	.070
Education	6.635	4	.156
Income	4.860	4	.302
Children	2.534	2	.282
Type of neighborhood	.907	4	.924

Statement 3: I am prepared to pay more for environmental friendly measures

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	15	32	62	109
		13.8%	29.4%	56.9%	100%
	Female	13	28	34	75%
		17.3%	37.3%	45.3%	100%
Age	21 to 30 years	11	20	29	60
		18.3%	33.3%	48.3%	100.0%
	31 to 50 years	9	16	47	72
		12.5%	22.2%	65.3%	100.0%
	> 50 years	8	24	20	52
		15.4%	46.2%	38.5%	100.0%
Education	Secondary	14	28	21	63
	vocational education	22.2%	44.4%	33.3%	100.0%
	Higher professional	6	25	42	73
	education	8.2%	34.2%	57.5%	100.0%
	Scientific education	8	7	33	48
		16.7%	14.6%	68.8%	100.0%
Income	0 to 25000 euro	10	18	7	35
		28.6%	51.4%	20.0%	100.0%
	25001 to 45000 euro	10	27	55	92
		10.9%	29.3%	59.8%	100.0%
	> 45000 euro	8	15	34	57
		14.0%	26.3%	59.6%	100.0%
Children	No children	15	41	51	107
		14.0%	38.3%	47.7%	100.0%
	Children	13	19	45	77
		16.9%	24.7%	58.4%	100.0%
Type of neighborhood	City center	6	8	24	38
		15.8%	21.1%	63.2%	100.0%
	Outside center	7	13	34	54
		13.0%	24.1%	63.0%	100.0%
	Village	15	39	38	92
		16.3%	42.4%	41.3%	100.0%
Total	Count	28	60	96	184
	% within statement 3	15.2%	32.6%	52.2%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	2.375	2	.305
Age	15.703	6	.033
Education	19.212	4	.001
Income	18.666	4	.001
Children	3.794	2	.150
Type of neighborhood	6.889	4	.142

Statement 4: The government should take more action against the climate problem

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	4	14	91	109
		3.7%	12.8%	83.5%	100%
	Female	1	9	65	75
		1.3%	12.0%	86.7%	100%
Age	21 to 30 years	3	8	49	60
		5.0%	13.3%	81.7%	100.0%
	31 to 50 years	1	8	63	72
		1.4%	11.1%	87.5%	100.0%
	> 50 years	1	7	44	52
		1.9%	13.5%	84.6%	100.0%
Education	Secondary	0	10	53	63
	vocational education	0.0%	15.9%	84.1%	100.0%
	Higher professional	4	7	62	73
	education	5.5%	9.6%	84.9%	100.0%
	Scientific education	1	6	41	48
		2.1%	12.5%	85.4%	100.0%
Income	0 to 25000 euro	3	3	29	35
		8.6%	8.6%	82.9%	100.0%
	25001 to 45000 euro	1	12	79	92
		1.1%	13.0%	85.9%	100.0%
	> 45000 euro	1	8	48	57
		1.8%	14.0%	84.2%	100.0%
Children	No children	4	13	90	107
		3.7%	12.1%	84.1%	100.0%
	Children	1	10	66	77
		1.3%	13.0%	85.7%	100.0%
Type of neighborhood	City center	2	2	34	38
		5.3%	5.3%	89.5%	100.0%
	Outside center	2	10	42	54
		3.7%	18.5%	77.8%	100.0%
	Village	1	11	80	92
		1.1%	12.0%	87.0%	100.0%
Total	Count	5	23	156	184
	% within statement 4	2.7%	12.5 %	84.8%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	.971	2	.615
Age	7.294	6	.726
Education	4.906	4	.297
Income	6.100	4	.192
Children	1.019	2	.601
Type of neighborhood	5.641	4	.228

Statement 5: I would like to be more independent of large energy providers

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	14	28	67	109
		12.8%	25.7%	61.5%	100%
	Female	18	23	34	75
		24.0%	30.7%	45.3%	100%
Age	21 to 30 years	18	12	30	60
		30.0%	20.0%	50.0%	100.0%
	31 to 50 years	8	23	41	72
		11.1%	31.9%	56.9%	100.0%
	> 50 years	6	16	30	52
		11.5%	30.8%	57.7%	100.0%
Education	Secondary	14	22	27	63
	vocational education	22.2%	34.9%	42.9%	100.0%
	Higher professional	9	19	45	73
	education	12.3%	26.0%	61.6%	100.0%
	Scientific education	9	10	29	48
		18.8%	20.8%	60.4%	100.0%
Income	0 to 25000 euro	11	9	15	35
		31.4%	25.7%	42.9%	100.0%
	25001 to 45000 euro	13	26	53	92
		14.1%	28.3%	57.6%	100.0%
	> 45000 euro	8	16	33	57
		14.0%	28.1%	57.9%	100.0%
Children	No children	23	26	58	107
		21.5%	24.3%	54.2%	100.0%
	Children	9	25	43	77
		11.7%	32.5%	55.8%	100.0%
Type of neighborhood	City center	9	10	19	38
		23.7%	26.3%	50.0%	100.0%
	Outside center	8	13	33	54
		14.8%	24.1%	61.1%	100.0%
	Village	15	28	49	92
		16.3%	30.4%	53.3%	100.0%
Total	Count	32	51	101	184
	% within statement 5	17.4%	27.7%	54.9%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	5.684	2	.058
Age	10.950	6	.033
Education	6.583	4	.160
Income	6.101	4	.192
Children	3.576	2	.167
Type of neighborhood	2.255	4	.689

Statement 6: I am willing to adopt a more environmental friendly lifestyle

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	2	18	89	109
		1.8%	16.5%	81.7%	100%
	Female	2	17	56	75
		2.7%	22.7%	74.7%	100%
Age	21 to 30 years	2	10	48	60
		3.3%	16.7%	80.0%	100.0%
	31 to 50 years	0	14	58	72
		0.0%	19.4%	80.6%	100.0%
	> 50 years	2	11	39	52
		3.8%	21.2%	75.0%	100.0%
Education	Secondary	2	18	43	63
	vocational education	3.2%	28.6%	68.3%	100.0%
	Higher professional	1	9	63	73
	education	1.4%	12.3%	86.3%	100.0%
	Scientific education	1	8	39	48
		1.4%	16.7%	81.3%	100.0%
Income	0 to 25000 euro	1	9	25	35
		2.9%	25.7%	71.4%	100.0%
	25001 to 45000 euro	3	15	74	92
		3.3%	16.3%	80.4%	100.0%
	> 45000 euro	0	11	46	57
		0.0%	19.3%	80.7%	100.0%
Children	No children	4	20%	83	107
		3.7%	18.7%	77.6%	100.0%
	Children	0	15	62	77
		0.0%	19.5%	80.5%	100.0%
Type of neighborhood	City center	2	5	31	38
		5.3%	13.2%	81.6%	100.0%
	Outside center	1	8	45	54
		1.9%	14.8%	83.3%	100.0%
	Village	1	22	69	92
		1.1%	23.9%	75.0%	100.0%
Total	Count	4	35	145	184
	% within statement 6	2.2%	19.0%	78.8%	100%

Pearson Chi-Square	***Value***	***Df***	***Asymptotic Significance (2-sided)***
Gender	1.301	2	.522
Age	9.429	6	.550
Education	6.836	4	.145
Income	3.297	4	.509
Children	2.943	2	.230
Type of neighborhood	4.887	4	.299

Statement 7: I would like to be seen with solar panels on my house

Attribute	Level	Disagree	Neutral	Agree	Total
Gender	Male	19	30	60	109
		17.4%	27.5%	55.0%	100%
	Female	22	23	30	75
		29.3%	30.7%	40.0%	100%
Age	21 to 30 years	11	16	33	60
		18.3%	26.7%	55.0%	100.0%
	31 to 50 years	14	20	38	72
		19.4%	27.8%	42.2%	100.0%
	> 50 years	16	17	19	52
		30.8%	32.7%	36.5%	100.0%
Education	Secondary	21	23	19	63
	vocational education	33.3%	36.5%	30.2%	100.0%
	Higher professional	12	19	42	73
	education	16.4%	26.0%	57.5%	100.0%
	Scientific education	8	11	29	48
		16.7%	22.9%	60.4%	100.0%
Income	0 to 25000 euro	12	8	15	35
		34.3%	22.9%	42.9%	100.0%
	25001 to 45000 euro	14	30	48	92
		15.2%	32.6%	52.2%	100.0%
	> 45000 euro	15	15	27	57
		26.3%	26.3%	47.4%	100.0%
Children	No children	26	27	54	107
		24.3%	25.2%	50.5%	100.0%
	Children	15	26	36	77
		19.5%	33.8%	46.8%	100.0%
Type of neighborhood	City center	8	11	19	38
		21.1%	28.9%	50.0%	100.0%
	Outside center	12	14	28	54
		22.2%	25.9%	51.9%	100.0%
	Village	21	28	43	92
		22.8%	30.4%	46.7%	100.0%
Total	Count	41	53	90	184
	% within statement 7	22.3%	28.8%	48.9%	100%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	5.033	2	.081
Age	6.969	6	.281
Education	14.260	4	.007
Income	6.245	4	.182
Children	1.725	2	.422
Type of neighborhood	.472	4	.976

Statement 8: I would participate in a prosumer community

Attribute	Level	Disagree	Neutral	Agree	Strongly agree	Total
Gender	Male	5	21	54	29	109
		4.6%	19.3%	49.5%	26.6%	100%
	Female	13	21	31	10	75
		17.3%	28.0%	41.3%	13.3%	100%
Age	21 to 30 years	3	15	29	13	60
		5.0%	25.0%	48.3%	21.7%	100.0%
	31 to 50 years	5	16	35	16	72
		6.9%	22.2%	48.6%	22.2%	100.0%
	> 50 years	10	11	21	10	52
		19.2%	31.4%	40.4%	19.2%	100.0%
Education	Secondary	12	16	30	5	63
	vocational education	19.0%	25.4%	47.6%	7.9%	100.0%
	Higher professional	5	17	35	16	73
	education	6.8%	23.3%	47.9%	21.9%	100.0%
	Scientific education	1	9	20	18	48
		2.1%	18.8%	41.7%	37.5%	100.0%
Income	0 to 25000 euro	6	12	11	6	35
		17.1%	34.3%	31.4%	17.1%	100.0%
	25001 to 45000 euro	9	18	45	20	92
		9.8%	19.6%	48.9%	21.7%	100.0%
	> 45000 euro	3	12	29	13	57
		5.3%	21.1%	50.9%	22.8%	100.0%
Children	No children	11	24	47	25	107
		10.3%	22.4%	43.9%	23.4%	100.0%
	Children	7	18	38	14	77
		9,1%	23.4%	49.4%	18.2%	100.0%
Type of neighborhood	City center	2	11	16	9	38
		5.3%	28.9%	42.1%	23.7%	100.0%
	Outside center	7	5	29	13	54
		13.0%	9.3%	53.7%	24.1%	100.0%
	Village	9	26	40	17	92
		9.8%	28.3%	43.5%	18.5%	100.0%

Pearson Chi-Square	***Value***	***df***	***Asymptotic Significance (2-sided)***
Gender	13.204	3	.004
Age	15.404	9	.268
Education	21.170	6	.002
Income	8.037	6	.233
Children	.935	3	.817
Type of neighborhood	9.107	6	.168

APPENDIX VII: Crosstabs Latent Class Model clusters

Gender * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Gender	Male	69	40	109
	Female	40	35	75
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.829[a]	1	.176		
Continuity Correction[b]	1.439	1	.230		
Likelihood Ratio	1.824	1	.177		
Fisher's Exact Test				.222	.115
Linear-by-Linear Association	1.819	1	.177		
N of Valid Cases	184				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 30.57.

b. Computed only for a 2x2 table

Age * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Age	21 to 30 years	42	18	60
	31 to 40 years	25	12	37
	41 to 50 years	18	17	35
	51 to 74 years	24	28	52
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.512[a]	3	.037
Likelihood Ratio	8.558	3	.036
Linear-by-Linear Association	7.957	1	.005
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.27.

Education * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Education	Secondary vocational education (mbo, mts)	30	33	63
	Higher professional education (hbo, pabo, hts, heao)	50	23	73
	Scientific education (university, promoted)	29	19	48
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.140[a]	2	.046
Likelihood Ratio	6.150	2	.046
Linear-by-Linear Association	3.568	1	.059
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 19.57.

Income * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Income	0 to 25000 euro	18	17	35
	25001 euro to 45000 euro	60	32	92
	>45000 euro	31	26	57
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.802[a]	2	.246
Likelihood Ratio	2.807	2	.246
Linear-by-Linear Association	.000	1	.994
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.27.

Children * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Children	No Children	66	41	107
	Children	43	34	77
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.632[a]	1	.427		
Continuity Correction[b]	.413	1	.520		
Likelihood Ratio	.631	1	.427		
Fisher's Exact Test				.450	.260
Linear-by-Linear Association	.629	1	.428		
N of Valid Cases	184				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 31.39.

b. Computed only for a 2x2 table

Type_neighborhood * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Type_neighborhood	Center	24	14	38
	Outside center	34	20	54
	Center village	51	41	92
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.103[a]	2	.576
Likelihood Ratio	1.104	2	.576
Linear-by-Linear Association	1.023	1	.312
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.49.

Property_ownership * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Property_ownership	Property owner	75	60	135
	Property renter	34	15	49
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.849[a]	1	.091		
Continuity Correction[b]	2.305	1	.129		
Likelihood Ratio	2.915	1	.088		
Fisher's Exact Test				.126	.063
Linear-by-Linear Association	2.833	1	.092		
N of Valid Cases	184				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 19.97.

b. Computed only for a 2x2 table

Household_composition * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Household_composition	1-person household	12	7	19
	2-person household	49	32	81
	3-person household	20	14	34
	4-person household'	28	22	50
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.393[a]	3	.942
Likelihood Ratio	.393	3	.942
Linear-by-Linear Association	.387	1	.534
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.74.

Innovation_adaptation * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
Innovation_adaptation	Innovators / early adopters	27	10	37
	Early majority	54	32	86
	Late majority / laggards	28	33	61
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.833[a]	2	.020
Likelihood Ratio	7.894	2	.019
Linear-by-Linear Association	7.585	1	.006
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.08.

I am worried about global warming * Class Crosstabulation

Count

		Class		Total
		Class 1	Class 2	
I am worried about global warming	Disagree	8	6	14
	Neutral	19	10	29
	Agree	82	59	141
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.567[a]	2	.753
Likelihood Ratio	.576	2	.750
Linear-by-Linear Association	.093	1	.760
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.71.

The majority of the population is not acting environmentally conscious * Class Crosstabulation

Count

		Class		Total
		Class 1	Class 2	
The majority of the population is not acting environmentally conscious	Disagree	4	5	9
	Neutral	16	8	24
	Agree	89	62	151
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.370[a]	2	.504
Likelihood Ratio	1.365	2	.505
Linear-by-Linear Association	.063	1	.801
N of Valid Cases	184		

a. 1 cells (16.7%) have expected count less than 5. The minimum expected count is 3.67.

I am prepared to pay more for environmental friendly measures * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
I am prepared to pay more for environmental friendly measures	Disagree	11	17	28
	Neutral	33	27	60
	Agree	65	31	96
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.915[a]	2	.019
Likelihood Ratio	7.885	2	.019
Linear-by-Linear Association	7.839	1	.005
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.41.

The government should take more action against the climate problem * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
The government should take more action against the climate problem	Disagree	2	3	5
	Neutral	13	10	23
	Agree	94	62	156
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.904[a]	2	.636
Likelihood Ratio	.886	2	.642
Linear-by-Linear Association	.722	1	.396
N of Valid Cases	184		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.04.

I would like to be more independent of large energy providers * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
I would like to be more independent of large energy providers	Disagree	11	21	32
	Neutral	26	25	51
	Agree	72	29	101
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.705[a]	2	.000
Likelihood Ratio	15.783	2	.000
Linear-by-Linear Association	15.573	1	.000
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 13.04.

I am willing to adopt a more environmental friendly lifestyle * Class Crosstabulation

Count

		Class		
		Class 1	Class 2	Total
I am willing to adopt a more environmental friendly lifestyle	Disagree	1	3	4
	Neutral	11	24	35
	Agree	97	48	145
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	16.674[a]	2	.000
Likelihood Ratio	16.563	2	.000
Linear-by-Linear Association	15.648	1	.000
N of Valid Cases	184		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.63.

I would like to be seen with solar panels on my house * Class Crosstabulation

Count

		Class		Total
		Class 1	Class 2	
I would like to be seen with solar panels on my house	Disagree	8	33	41
	Neutral	33	20	53
	Agree	68	22	90
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	36.922[a]	2	.000
Likelihood Ratio	37.928	2	.000
Linear-by-Linear Association	33.500	1	.000
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.71.

I would participate in a prosumer community * Class Crosstabulation

Count

		Class		Total
		Class 1	Class 2	
I would participate in a prosumer community	Disagree	2	16	18
	Neutral	21	21	42
	Agree	54	31	85
	Strongly agree	32	7	39
Total		109	75	184

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	27.805[a]	3	.000
Likelihood Ratio	29.736	3	.000
Linear-by-Linear Association	25.789	1	.000
N of Valid Cases	184		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.34.

APPENDIX VIII: Data analysis

Code NLogit

MNL model:

```
Reset $
Read; File= C:\Users\Luc de Vet\Dropbox\Graduation project CME\5.
Methodology\4. Clusters\Statedchoice_input_NLogit.csv $

Nlogit
 ; lhs = choice,Nalt
 ; rhs = const1, const2, fcoi1, fcoi2, ppoi1, ppoi2, caoi1, caoi2, opoi1,
opoi2, fcout1, fcout2, ppout1, ppout2, caout1, caout2, opout1, opout2,
$
```

Latent Class model:

```
Nlogit
 ; lhs = choice,Nalt
 ; rhs = const1, const2, fcoi1, fcoi2, ppoi1, ppoi2, caoi1, caoi2, opoi1,
opoi2, fcout1, fcout2, ppout1, ppout2, caout1, caout2, opout1, opout2
 ; lcm
 ; pds=9
 ; pts=2
 ; parameters
 ; maxit=200
$
```

Null model LL(0):

```
Create; null=0 $
Nlogit
 ; lhs = choice,Nalt
 ; rhs = null
 ; check
$
```

MNL output

```
|-> Reset $
|-> Read; File=C:\Users\Luc de Vet\Dropbox\Graduation project CME\5.
Methodology\4. Clusters\Statedchoice_input_NLogit.csv $
Last observation read from data file was     4968
|-> Nlogit
    ; lhs = choice,Nalt
    ; rhs = const1, const2, fcoi1, fcoi2, ppoi1, ppoi2, caoi1, caoi2, opoi1,
opoi2,
    fcout1, fcout2, ppout1, ppout2, caout1, caout2, opout1, opout2
    $
Normal exit:   5 iterations. Status=0, F=    1645.903
```

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -1645.90298
Estimation based on N =   1656, K =  18
Inf.Cr.AIC  =   3327.8 AIC/N =    2.010
Model estimated: Jun 05, 2018, 21:49:26
R2=1-LogL/LogL* Log-L fncn R-sqrd R2Adj
Constants only must be computed directly
               Use NLOGIT ;...;RHS=ONE$
Response data are given as ind. choices
Number of obs.=  1656, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
  CHOICE|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
  CONST1|     .00553        .07453      .07  .9408     -.14055     .15161
  CONST2|    -.06074        .08232     -.74  .4606     -.22208     .10060
   FCOI1|    1.12998***     .09464    11.94  .0000      .94449    1.31546
   FCOI2|    -.31687***     .11501    -2.76  .0059     -.54228    -.09146
   PPOI1|    -.08944        .10555     -.85  .3967     -.29631     .11742
   PPOI2|    -.03950        .09000     -.44  .6607     -.21589     .13688
   CAOI1|     .27511***     .09206     2.99  .0028      .09468     .45554
   CAOI2|     .10354        .10679      .97  .3322     -.10576     .31284
   OPOI1|    -.24605***     .08914    -2.76  .0058     -.42076    -.07134
   OPOI2|     .17203        .10920     1.58  .1152     -.04200     .38606
  FCOUT1|     .26722***     .08655     3.09  .0020      .09759     .43684
  FCOUT2|    -.02403        .09768     -.25  .8057     -.21547     .16742
  PPOUT1|    -.19913*       .11242    -1.77  .0765     -.41948     .02121
  PPOUT2|     .02962        .14961      .20  .8431     -.26361     .32284
  CAOUT1|     .21492*       .11969     1.80  .0725     -.01966     .44950
  CAOUT2|     .01760        .07713      .23  .8195     -.13357     .16878
  OPOUT1|    -.19609*       .10148    -1.93  .0533     -.39499     .00282
  OPOUT2|     .09611        .09207     1.04  .2965     -.08434     .27656
--------+--------------------------------------------------------------------
Note: ***, **, * ==>  Significance at 1%, 5%, 10% level.
-----------------------------------------------------------------------------
```

LCM output

```
|-> Nlogit
    ; lhs = choice,Nalt
    ; rhs = const1, const2, fcoi1, fcoi2, ppoi1, ppoi2, caoi1, caoi2, opoi1,
opoi2,
    fcout1, fcout2, ppout1, ppout2, caout1, caout2, opout1, opout2
    ; lcm
    ; pds=9
    ; pts=2
    ; parameters
    ; maxit=200
    $
Normal exit:   5 iterations. Status=0, F=    1645.903

---------------------------------------------------------------------------
Discrete choice (multinomial logit) model
```

```
Dependent variable                  Choice
Log likelihood function        -1645.90298
Estimation based on N =    1656, K =   18
Inf.Cr.AIC  =    3327.8 AIC/N =    2.010
Model estimated: Jun 05, 2018, 20:24:13
R2=1-LogL/LogL* Log-L fncn R-sqrd R2Adj
Constants only must be computed directly
               Use NLOGIT ;...;RHS=ONE$
Response data are given as ind. choices
Number of obs.=  1656, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.       95% Confidence
  CHOICE|  Coefficient       Error       z     |z|>Z*         Interval
--------+--------------------------------------------------------------------
CONST1|1|     .00553         .07453       .07  .9408     -.14055     .15161
CONST2|1|    -.06074         .08232      -.74  .4606     -.22208     .10060
 FCOI1|1|    1.12998***      .09464     11.94  .0000      .94449    1.31546
 FCOI2|1|    -.31687***      .11501     -2.76  .0059     -.54228    -.09146
 PPOI1|1|    -.08944         .10555      -.85  .3967     -.29631     .11742
 PPOI2|1|    -.03950         .09000      -.44  .6607     -.21589     .13688
 CAOI1|1|     .27511***      .09206      2.99  .0028      .09468     .45554
 CAOI2|1|     .10354         .10679       .97  .3322     -.10576     .31284
 OPOI1|1|    -.24605***      .08914     -2.76  .0058     -.42076    -.07134
 OPOI2|1|     .17203         .10920      1.58  .1152     -.04200     .38606
FCOUT1|1|     .26722***      .08655      3.09  .0020      .09759     .43684
FCOUT2|1|    -.02403         .09768      -.25  .8057     -.21547     .16742
PPOUT1|1|    -.19913*        .11242     -1.77  .0765     -.41948     .02121
PPOUT2|1|     .02962         .14961       .20  .8431     -.26361     .32284
CAOUT1|1|     .21492*        .11969      1.80  .0725     -.01966     .44950
CAOUT2|1|     .01760         .07713       .23  .8195     -.13357     .16878
OPOUT1|1|    -.19609*        .10148     -1.93  .0533     -.39499     .00282
OPOUT2|1|     .09611         .09207      1.04  .2965     -.08434     .27656
--------+--------------------------------------------------------------------
Note: ***, **, * ==>  Significance at 1%, 5%, 10% level.
-----------------------------------------------------------------------------

Line search at iteration   54 does not improve fn. Exiting optimization.

-----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                  CHOICE
Log likelihood function        -1338.89544
Restricted log likelihood      -1819.30195
Chi squared [  37 d.f.]         960.81302
Significance level                 .00000
McFadden Pseudo R-squared        .2640609
Estimation based on N =    1656, K =   37
Inf.Cr.AIC  =    2751.8 AIC/N =    1.662
Model estimated: Jun 05, 2018, 20:24:21
Constants only must be computed directly
               Use NLOGIT ;...;RHS=ONE$
At start values -1645.9035  .1865******
Response data are given as ind. choices
Number of latent classes =            2
Average Class Probabilities
     .593  .407
LCM model with panel has     184 groups
```

Fixed number of obsrvs./group= 9
Number of obs.= 1656, skipped 0 obs

CHOICE	Coefficient	Standard Error	z	Prob. |z|>Z*	95% Confidence Interval	
	Utility parameters in latent class -->> 1					
CONST1|1	1.87587***	.17665	10.62	.0000	1.52965	2.22210
CONST2|1	1.76280***	.18347	9.61	.0000	1.40321	2.12238
FCOI1|1	1.05158***	.14863	7.08	.0000	.76027	1.34288
FCOI2|1	-.12922	.16545	-.78	.4348	-.45350	.19505
PPOI1|1	-.15220	.14642	-1.04	.2986	-.43917	.13477
PPOI2|1	.13121	.13771	.95	.3407	-.13870	.40112
CAOI1|1	.25417**	.12089	2.10	.0355	.01723	.49111
CAOI2|1	.20082	.14520	1.38	.1666	-.08376	.48540
OPOI1|1	-.16441	.11613	-1.42	.1568	-.39203	.06320
OPOI2|1	-.00501	.15321	-.03	.9739	-.30530	.29528
FCOUT1|1	.00714	.12560	.06	.9547	-.23903	.25330
FCOUT2|1	-.00235	.13576	-.02	.9862	-.26844	.26374
PPOUT1|1	-.23088	.15614	-1.48	.1392	-.53691	.07515
PPOUT2|1	-.07230	.20769	-.35	.7278	-.47936	.33476
CAOUT1|1	.33152*	.17147	1.93	.0532	-.00456	.66759
CAOUT2|1	.04251	.10891	.39	.6963	-.17096	.25597
OPOUT1|1	-.21560	.15261	-1.41	.1577	-.51470	.08351
OPOUT2|1	.07662	.13651	.56	.5746	-.19094	.34417
	Utility parameters in latent class -->> 2					
CONST1|2	-2.18130***	.25035	-8.71	.0000	-2.67198	-1.69061
CONST2|2	-1.85559***	.20096	-9.23	.0000	-2.24946	-1.46173
FCOI1|2	2.22141***	.28196	7.88	.0000	1.66878	2.77404
FCOI2|2	-.61749	.37986	-1.63	.1040	-1.36200	.12703
PPOI1|2	-.35824	.22454	-1.60	.1106	-.79832	.08185
PPOI2|2	-.21420	.21248	-1.01	.3134	-.63066	.20226
CAOI1|2	.48639**	.23951	2.03	.0423	.01696	.95582
CAOI2|2	-.04886	.21514	-.23	.8203	-.47053	.37280
OPOI1|2	-.33286	.21306	-1.56	.1182	-.75045	.08474
OPOI2|2	.48682*	.26153	1.86	.0627	-.02577	.99940
FCOUT1|2	1.13687***	.20875	5.45	.0000	.72774	1.54600
FCOUT2|2	-.19512	.22182	-.88	.3791	-.62987	.23964
PPOUT1|2	-.50157**	.22533	-2.23	.0260	-.94321	-.05992
PPOUT2|2	.53393*	.27655	1.93	.0535	-.00809	1.07595
CAOUT1|2	.40965*	.23770	1.72	.0848	-.05623	.87552
CAOUT2|2	-.03521	.16972	-.21	.8357	-.36786	.29745
OPOUT1|2	-.48256**	.22764	-2.12	.0340	-.92872	-.03639
OPOUT2|2	.36776*	.20630	1.78	.0746	-.03658	.77210
	Estimated latent class probabilities					
PrbCls1	.59324***	.03881	15.29	.0000	.51718	.66929
PrbCls2	.40676***	.03881	10.48	.0000	.33071	.48282

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.