Utrecht University

Master Thesis

Energy exchange between households

What are the preferences for exchanging locally generated renewable energy in the Netherlands?

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Summary

With the increasing deployment of renewable distributed energy resources (DER), centralised electricity grids will face issues regarding the balance of supply and demand. Additionally, feeding surplus energy into centralised grids will become decreasingly economically attractive for households producing and consuming electricity, so-called prosumers, due to policy changes in the Netherlands. These two developments pave the way for alternative electricity trading schemes like peer-to-peer (P2P) electricity trading where prosumers can trade surplus electricity directly with peers in a local electricity market (LEM). By conducting a survey including a discrete choice experiment (DCE) with prosumers in the Netherlands, the electricity trading preferences regarding six parameters (CO_2 emissions, selling price, social connection with electricity trading partner, additional effort, improved efficiency, self-sufficiency) were elicited. Several sub-groups were identified based on participants' characteristics and compared in regard to their stated preferences. The results reveal that prosumers attach the most importance to CO_2 emissions (38%) and to the additional effort in terms of time (20%) required when participating in electricity trading. The four remaining factors selling price, improved efficiency, self-sufficiency and social connection with the electricity trading partner have less impact on trading behaviour (approx. 10% each). Energy cooperative members attach less importance to economic factors compared to non-members, so do prosumers who are highly environmentally conscious and prosumers who are willing to provide surplus electricity for free. When asked directly, a majority of prosumers stated they would give surplus electricity for free (60%) or for a non-monetary compensation (76%). The findings highlight that the environmental aspect play the most important role for prosumers. Therefore, the benefits of P2P trading for the environment due to more employment of DER, efficiency improvements and reduced electricity losses should be communicated when marketing a P2P electricity trading platform. The findings also give insights into important design features for P2P electricity trading platforms, such as little time investments for users and the possibility to personalise trades according to individual preferences.

Keywords: P2P electricity trading, local electricity markets, discrete choice experiments, prosumers, energy cooperatives

Content

List of Abbreviations

B-DER	(name of project) A Blockchain-based platform for peer-to-peer energy transactions between distributed energy resources
DER	distributed energy resources
DCE	discrete choice experiment
EC	European Commission
EU	European Union
FiT	Feed-in tariff
HB	Hierarchical Bayes
LEM	local electricity markets
P2P	peer-to-peer
PV	photovoltaics
RE	renewable energy
RES	renewable energy system
SD	standard deviation
SDG	sustainable development goals
UN	United Nations

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1 Introduction

1.1 Background

In 2016, by signing the Paris Agreement the government of the Netherlands has committed to significantly reduce the emissions of greenhouse gases in order to keep global warming at a maximum of 1.5 degrees above pre-industrial levels (United Nations, 2016). To achieve this goal, the Dutch government made commitments which include an increase of the share of renewable energy from seven percent in 2015 (IEA, 2020) to 19-24% in 2030 (Ministry of Economic Affairs of the Netherlands, 2016). An integral part of the renewable energy transition is the promotion of renewable energy technologies for households, for example in the form of solar photovoltaics (PV) panels installed on roof tops. These devices are also referred to as distributed energy resources (DER), which are electric power generating resources that are directly connected to a medium- or low-voltage distribution network (Akorede, Hizam, & Pouresmaeil, 2010). Actors who produce and consume their own energy are known as prosumers (Parag & Sovacool, 2016). In order to have access to electricity in times of insufficient supply or to feed-in surplus electricity in times of over-production, prosumers are still connected to an electricity grid. For the majority of prosumers in the Netherlands, the status quo is that the surplus electricity produced is fed into a central electricity grid under a net metering scheme. This net metering scheme allows prosumers to extract and feed electricity to the grid for the same price; from the moment annual electricity imports exceed exports, a lower rate is paid for fed-in electricity (Manrique Delgado et al., 2018). From 2023, the Dutch government plans to replace this scheme by the *terugleversubsidie* (Rijksoverheid, 2019), a return subsidy comparable to a feed-in tariff (FiT), which will effectively decrease the financial return for prosumers.

Local electricity markets (LEM) in which prosumers trade surplus electricity directly with a community or peers represent an alternative to the dependence on centralised grids and their hierarchical structure (Mengelkamp, Staudt, Garttner, Weinhardt, & Huber, 2018). The design of grids for LEM requires additional technical features like smart meters and a platform that allows for advanced management of electricity generation, consumption and trading (Parag & Sovacool, 2016). The smart decentralised grids enable prosumers to participate in LEM where they can exchange electricity in a peer-to-peer (P2P) trading scheme. As a reaction to the rise of DER and a trend for cooperation and participation, P2P electricity trading schemes have been increasingly addressed in scientific literature in the last ten years (Giotitsas, Pazaitis, & Kostakis, 2015). An indicator of this trend is the rise of energy cooperatives, who often formed as a counterpart to the market-driven energy system and who pursue more social and environmental values (Bakker, Lagendijk, & Wiering, 2020). Energy cooperatives represent an organised form of local communities that “promote production and consumption of renewable energies” (Kooij et al., 2018) and can play an important role in the formation of LEM.

1.2 Problem definition and knowledge gap

The increasing deployment of DERs comes with opportunities and challenges. Although they can increase efficiency and reduce CO_2 emissions when appropriately managed, this management requires advanced mechanisms. A centralised electricity grid will face issues regarding the balance of supply and demand when more DERs from variable energy sources are installed (Rommel & Sagebiel, 2017) and they become decreasingly financially attractive for prosumers due to policy changes

(Rijksoverheid, 2019). Decentralised smart grids provide a solution to this problem while also offering the opportunity for forming LEMs with P2P trading schemes (Sousa et al., 2019).

The technical requirements for P2P electricity trading are addressed by the research project B-DER: *A Blockchain-based platform for peer-to-peer energy transactions between distributed energy resources* (Topsector Energie, 2020). The aim of the project is the development of a P2P electricity trading platform based in blockchain architecture to enable prosumer to maximise the selling of their surplus electricity and thereby minimise electricity costs (UU News, 2019). Thereby, the B-DER project strives to close the knowledge gap regarding the optimal utilization of DERs in local decentralised energy grids.

Apart from the technical solutions required to successfully implement a P2P electricity trading platform, it must be investigated what prosumers' preferences are regarding the features of such a trading scheme. Recently, more research has been conducted around identifying these preferences and other drivers and barriers, which is reviewed in more detail in Chapter 2 (Ecker, Spada, & Hahnel, 2018; Hackbarth & Löbbe, 2020; Hahnel, Herberz, Pena-Bello, Parra, & Brosch, 2020; Mengelkamp, Schönland, Huber, & Weinhardt, 2019; Mengelkamp et al., 2018; Reuter & Loock, 2017; Wilkinson, Hojckova, Eon, Morrison, & Sandén, 2020). The research conducted in this thesis extends the existing literature on individuals' preferences for P2P electricity trading in the following ways. In contrast to previous research, solely prosumers are surveyed, which is expected to yield more valid results because respondents have more insight into the matter of investigation. Besides, the surveyed prosumers were residents of the Netherlands, while the aforementioned research was conducted in other locations. Furthermore, the primary focus of the study is eliciting preferences of P2P trading, while other research only included this matter as part of a wider objective. Additionally, like in any other exchange or trade, the giving party will expect a compensation for the provided electricity. In a field research carried out in rural India, Singh et al. (2018) found that preferred returns for energy provided to peers can vary. Preferred returns for generated electricity may be of monetary or non-monetary nature and may be dependent on the prosumer's personal relationship with their peer or community. Based on their findings, the researchers recommended to also investigate preferences in mutual energy exchange in other settings and more economically developed countries.

1.3 Scientific and societal relevance

This master thesis contributes to the existing body of scientific literature on P2P electricity trading in decentralised grids by investigating the social components that drive the acceptance and thereby success of such systems. Currently, the main focus of researchers lies on the technical components and market designs required to implement this novel trading scheme. By conducting a survey with prosumers in the Netherlands to understand their preferences for local renewable electricity exchange, this research can add valuable insights by acknowledging that the concept has to be looked at from multiple disciplinary perspectives. Thereby, this research follows the recommendation of Singh et al. (2018) to look further into the influence of social relations on return preferences and can serve as a starting point for future research projects to ultimately understand all relevant components in P2P trading systems.

Concerning its relevance for society, this research addresses issues of individual stakeholders, i.e. prosumers, and society as a whole. Firstly, it provides insights for the success of P2P electricity trading as a solution for prosumers who want to increase their autonomy from energy suppliers and grid operators. Secondly, the research promotes the increase of DERs and their efficient utilization, and thereby the increase of renewable energy sources. This links it to the seventh sustainable development goal (SDG) set by the United Nations (UN), which states that member states should take efforts to ensure access to affordable and clean energy for all (United Nations, 2015). An increasing effort to decarbonise electricity generation will lead to a reduction of CO_2 emissions and their harmful consequences for the environment and today's as well as future societies.

1.4 Research objective and research questions

Following the above defined problem and the corresponding knowledge gap, the research goal of this master thesis is to explore the preferences of prosumers regarding P2P electricity exchange by conducting a questionnaire-based survey with prosumers in the Netherlands. Next to questions asking for participant's characteristics as a prosumer and their attitudes towards the environment, their community and technology, a discrete choice experiment (DCE) was carried out to elicit their preferences for trading surplus electricity. A DCE is a quantitative attribute-based survey technique commonly used for assessing individual's preferences, based on their choices regarding attributes which characterise the alternatives within the present decision-making problem (Mangham et al., 2009).

The scope of the data collection is limited to the Netherlands as this research is part of the larger project B-DER: *A Blockchain-based platform for peer-to-peer energy transactions between distributed energy resource* which is based in the Netherlands. The findings of this thesis will contribute to this larger project by answering the following research question:

What are the preferences of prosumers for peer-to-peer exchange of locally generated renewable electricity in the Netherlands?

Next to this main research question, the following two sub-questions are addressed.

1. *How do the preferences regarding P2P electricity trading differ between prosumer subgroups with different socio-economic characteristics, prosumer characteristics and attitudes influence?*
2. *Are prosumers willing to exchange surplus electricity for free of for non-monetary compensation?*

The remainder of this thesis is structed as follows. Chapter 2 Theory provides an overview of the relevant literature on prosumer, energy communities and cooperatives, and P2P electricity trading. In Chapter 3 Methods the design process of the survey and the data collection process are described. The results obtained through the analysis of the questionnaire-based survey and the DCE method are presented in Chapter 4 Results. In Chapter 5 Discussion, the results are discussed and recommendations for the B-DER project are derived. And finally, Chapter 6 Conclusion gives a conclusion of the main findings and their implications.

2 Theory

The theory chapter is organised in the following way. In Section 2.1 Prosumers and energy cooperatives and communities, the development of prosumers and energy communities in the Netherlands is described in terms of policies, motivations and barriers. The Section 2.2 Peer-to-peer electricity trading systems reviews the current state of literature on P2P electricity trading systems is, including an excursus to alternative returns for P2P electricity exchange. In Section 2.3 Intention-behaviour gap, the intention-behaviour gap is shortly described as a foundation for applicability of the survey's results. And finally, the conceptual framework, that was derived from the presented literature review and that serves as basis of the data collection, is described in Section 2.4 Conceptual framework.

2.1 Prosumers and energy cooperatives and communities

After the first oil crisis in 1973, the Netherlands developed a market for renewable energy starting with research and development, and since then the Dutch government has steered the deployment of renewable energy generation with a variety of policies and mechanisms (van Rooijen & van Wees, 2006). At first solar and wind projects were mostly driven by idealistic motives, but in the 1980s new policies were set up that incentivised investors with subsidies in order to accelerate market growth, thereby moving towards an economy of scale and reducing costs (van Rooijen & van Wees, 2006). In the 1990s, the discussion about climate change boosted policy making and consequently the respective instruments, for example consumer subsidies, were implemented (van Rooijen & van Wees, 2006). These efforts increased the share of renewable electricity consumption from 0.9% in 1990 to 15% in 2018 (Eurostat, 2020). Apart from large scale projects, these instruments have also motivated individuals to produce their own renewable electricity, i.e. becoming prosumers, and the forming of collectives that realise renewable electricity projects, i.e. organised energy cooperatives and communities. These two bottom-up approaches to renewable electricity generation – one in an individual and one in a collective manner - will be elaborated in the following two sections.

2.1.1 Prosumers: the individual approach

Developments and policies for prosumers in the Netherlands.

The installation of renewable DER by residential prosumers in the Netherlands emerged in the late 1990s when the Ministry of Economic Affairs financed a project that significantly reduced investment costs of PV systems for households (Verhees, Raven, Veraart, Smith, & Kern, 2013). With the introduction of a new subsidy scheme for the purchase of PV systems in 2000, their number increased rapidly, until in 2003 the newly elected ruling party suddenly stopped the subsidy scheme leading to a stagnation in the number of new installations. In 2008, subsidies were put back into place and together with the net metering scheme the number of installations started to increase again (Londo et al., 2020; Verhees et al., 2013). Today, prosumers must be compensated by energy suppliers for the surplus electricity they feed into the grid based on the net metering scheme. The energy bill provided to them must state the amount of produced electricity as well as how much was delivered by the supplier. The installation of solar panels on one's home does not require a building permit but can be checked with an online tool provided by the Ministry for Infrastructure and Environment (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). From 2016 until the end of 2030, businesses and private individuals can collect an investment subsidy for the purchase of water heaters, heat pumps, biomass boilers and pellet stoves under the ISDE subsidy scheme, while investment subsidies for PV were discontinued (Rijksdienst voor Ondernemend, 2020). Owners of PV panels can reclaim the VAT (currently 21%) (Belastingdienst, 2020) on purchasing and installing solar panels and are eligible for an exempt of the environmental protection tax rebate (Anciaux, 2019).

Motives and barriers for prosumers.

Homeowners who were early adopters of PV installations were mostly motivated by environmental reasons and wanted to set an example. Today, for many prosumers environmental motives still play a major role, but also becoming independent from energy companies, making a profitable investment and curiosity about the technology (Palm, 2018). Homeowners are more likely to adopt PV systems when the system is affordable, profitable and leads to increased self-sufficiency. Other predictors for adoption are an easy application, environmental benefits and feeling well-informed about existing subsidies. A good knowledge about the involved costs and the existing subsidies showed significant positive impact on adoption of PV in the Netherlands (Vasseur & Kemp, 2015).

Regarding perceived barriers, earlier homeowners were mostly put off by high investment costs, a lack of regulations and little experience with the technology and installation. Although the high investment costs are still a barrier today, administrative issues and difficulties in the process of feeding-in and selling surplus electricity are seen as higher obstacles. For some, the variety of options on the market feels overwhelming and a lack of objective information is perceived (Palm, 2018). Peer effects can reduce barriers related to the perceived complexity of the technology. Peer effects were strongest in existing social networks, e.g., friends and relatives, and less so with unknown neighbours, i.e. a passive peer effect like seeing PV panels on roofs (Palm, 2017). When peer effects exist, 13% decided to install PV primarily because of these peers (Rai, Reeves, & Margolis, 2016). Suggestions followed for policy makers to not only focus on financial factors, but to acknowledge the positive impact of existing PV installations in neighbourhoods on newly installed PV panels (Curtius, Hille, Berger, Hahnel, & Wüstenhagen, 2018).

2.1.2 Energy cooperatives and communities: the collective approach

When conducting research on prosumers, it is recommendable to also look at energy communities and cooperatives, because many prosumers are members of such. Members of these communities are often more informed and interested in developments of the technologies, markets and policies around renewable energy. They may also be keener in participating in P2P electricity trading as many inherit communal values. The following paragraphs elaborate on the development and policies around energy communities in the Netherlands and review literature which concerns the motives and barriers for participating in energy communities.

Developments and policies of energy communities in the EU and the Netherlands.

Governments around the world have set goals with the Paris agreement regarding the transition to more renewable energy, yet most countries' governments alone do not have the capital to make the necessary investments to achieve these goals (Bauwens, 2016; Wüstenhagen & Menichetti, 2012). Energy communities and cooperatives support these goals by investing in and developing sustainable energy projects. In 2019, the Netherlands had 582 - a hundred more than in 2018 - energy cooperatives with an estimate of 85,000 members. Eighty percent of cooperatives developed collective solar projects (of which 94% are roof installations) and 25% were involved in wind projects (HIER opgewekt & RVO, 2019). The increase of organised prosumer groups raises the demand of new legal frameworks that allow the selling of surplus energy directly to another consumer, like P2P trading (Inês et al., 2020).

The EU's Renewable Energy Directive 2018/2001 (or RED II) defines renewable energy communities (RECs) as "legal entities which are optional, member-controlled organisations proximate to RE (renewable energy) projects they own or operate". They must be "non corporate actors, and whose primary purpose are social, economic, or environmental outcomes beyond financial profit" (Inês et al., 2020). RECs are allowed to self-arrange sharing of renewable energy within the community and to access all suitable energy markets directly (EU, 2018; Inês et al., 2020). As a member state, the Netherlands have to comply with the EU directive, but the country also has its own regulatory framework for collective prosumers. The postal-code-area regulation enables local energy cooperatives to supply their own members with electricity (ECoop, 2020). When members of an energy cooperative want to exchange electricity among themselves, they will need to share the same postal code in order to apply to the net metering law and be eligible for tax advantages (Inês et al., 2020; Kooij et al., 2018). This allows prosumers to participate in retail electricity markets, for which they need to have a status as a supplier (Inês et al., 2020).

Motivations and barriers of energy communities.

Community renewable energy projects can ideally be classified as open and participatory in terms of their processes, and local and collective in terms of their outcome (Walker & Devine-Wright, 2008). Members of energy communities differ in terms of their attitudes towards energy when compared to non-members. They are significantly more in favour of RE than non-members who feel generally more indifferent about RE. This is also the case for those energy cooperative members who are characterised by lower levels of environmentalism and who are mostly driven by financial motives. This implies that policy makers should still focus on financially incentivizing community RE projects to enhance participation (Bauwens & Devine-Wright, 2018).

Community energy projects contribute to several benefits for societies. Most of the mentioned benefits in literature are of economic nature, for example in regard to direct financial gains from revenues generated from selling electricity, or by stimulating the regional economy through creating jobs related to RE installations. Other benefits regard education and acceptance associated with a better understanding of RE technologies, increased participation of citizens in political processes, climate protection through sustainable lifestyle choices, increased community building and identities, contributions to achieving RE targets set by governments, and finally technological innovations (Brummer, 2018). Investigated Dutch energy communities stated they wanted to save money on the long term, make use of the subsidies in place, and they feared an increase of oil prices. Environmentally driven motives were also stated, as well as being part of a collaboration and more independent from energy companies (Brummer, 2018). Energy cooperative being driven by collaborative action while having environmental and financial motives at the same time, is an indication for their potential role as early adopters and facilitator of P2P electricity trading.

Currently, there are still barriers which hinder community energy projects. Many are related to organizational issues, legal frameworks and planning requirements. Another issue is the discrimination against community energy on the market which is designed for big energy companies. This issue is related to a general lack of institutional and political support. Many energy communities struggle with scepticism against RE, which often results in a NIMBY ("not in my backyard") attitude - for example when windmills in inhabited areas are proposed. One of the biggest barriers is the lack of financial resources and time and expertise to realise RE projects. Finally, there are already saturation effects in some regions, like insufficient appropriate sites for RE projects (Brummer, 2018).

2.2 Peer-to-peer electricity trading systems

The overarching concept behind this research project is the idea that prosumers can directly exchange the surplus electricity generated by their DER with other households, i.e. peers. This provides an alternative to feeding surplus electricity into the grid, whereby prosumers have the possibility to optimise the utilization of the DER in terms of financial returns and the balance of supply and demand (Jogunola et al., 2017; van Leeuwen, AlSkaif, Gibescu, & van Sark, 2020). P2P trading can reduce the mismatch of local renewable electricity supply and demand that occurs in many households due to their demand profiles by controlling energy transfers with other household whose demand matches the supply. Thereby demand costs can be reduced up to 20% and CO_2 emissions are lowered as less electricity from the central grid is required (AlSkaif, Zapata, Bellalta, & Nilsson, 2017). Jogunola et al. (2017) classify energy trading into the three areas *Motivation/Desired outcome, Enabling technologies and Required frameworks* as can be seen in Figure 1. The B-DER project's primary objective is to design a trading platform, thereby covering the technical aspect of energy trading, i.e. the two areas *Enabling technologies* and *Required frameworks*. This research focuses on the *Motivation/Desired outcome* of energy trading. According to Jogunola et al. (2017) this is the first step in an energy trading scheme, where actors decide "on what they want to achieve in the trading and sharing of energy." Next to the improvement of network agility, system efficiency and cost optimization, this may also be socially motivated as providing surplus energy to peers.

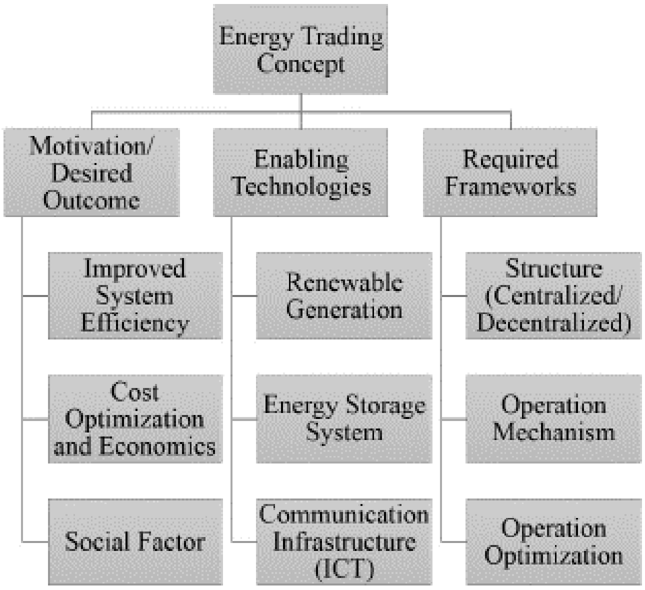

Figure 1. Energy trading concept according to Jogunola et al. (2017), adapted from Bayram, Shakir, Abdallah, & Qaraqe (2014).

2.2.1 Characteristics of P2P electricity markets

Different designs for P2P electricity market have been proposed in literature. Sousa et al. (2019) classify three systems for P2P electricity trading. A full P2P market enables peers to directly negotiate to sell and buy electricity without centralised supervision. This system allows participants to express preferences, for example regarding the extent to which the purchased electricity is green or local. In a community-based market the system is more structured and includes a community manager who manages trading activities among the peers anonymously and who coordinates the imports to and exports from an outside grid. A hybrid P2P market combines the two systems, giving peers the option to interact directly with each other in an upper level and to trade with a community manager on the lower level. The authors conclude that the hybrid model is most suitable in terms of scalability as it gives room for both P2P designs to interact, although the coordination of trades on the different levels can be complex.

Through transparent P2P market mechanisms, prosumers can balance their preferences and requirements (Morstyn, Farrell, Darby, & McCulloch, 2018). To coordinate electricity trading between prosumers with heterogeneous preferences, the platform can include information beyond price like generation technology, location in the network and the owner's reputation, which give prosumers the added value of choosing trading partners according to their preferences (Morstyn & McCulloch, 2019). Also, P2P electricity trading can be an opportunity to provide electricity to everyone in a more equal and just manner (Giotitsas et al., 2015; Ruotsalainen, Karjalainen, Child, & Heinonen, 2017). P2P encourages to share resources for the benefit of individuals, communities and the wider society leading to more energy efficiency and a democratization of energy (Parag & Sovacool, 2016).

When surplus electricity is sold via a P2P trading scheme, households can supply their demand at lower cost by trading electricity with a community, compared to interacting individually with the centralised electricity system (Heinisch, Odenberger, Göransson, & Johnsson, 2019). Costs are also minimised through efficiency improvements, and prosumers can adjust power flows based on actual and predicted energy prices, as well as generation and loads (Morstyn & McCulloch, 2019). Energy matching of P2P trading partners reduces losses by increasing local utilization of variable renewable sources. By aggregating prosumers which are physically dispersed or use different technologies for generation, the electric load variability can be reduced (Morstyn et al., 2018). Furthermore, the improved utilization of DER involves environmental benefits as less grid electricity from fossil resources is required and less energy is lost due to long transmission distances (Jogunola et al., 2017). Energy storage plays a valuable role in a P2P trading system both for efficient use of energy and for profitability, because DERs usually produce irregular output and supply and demand can be regulated with additional batteries (Park & Yong, 2017). P2P trading that includes energy storage can produce savings of up to 31% for end-users, of which half comes from the community trades and the other half from the battery's balancing function (Lüth, Zepter, Crespo del Granado, & Egging, 2018).

While the application of blockchain technology itself is fairly new and so is the idea of applying it in energy trading (Livingston, Sivaram, Freeman, & Fiege, 2008), a blockchain architecture behind P2P trading platforms can ensure secure and verifiable energy transactions (van Leeuwen et al., 2020). The principal behind blockchain is to provide data structures that can securely store digital transaction without using a central point of control (Andoni et al., 2019). In the case of electricity trading, blockchain can therefore facilitate the introduction of decentralised local electricity markets in which prosumers play an active role (Buth, Wieczorek, & Verbong, 2019). A blockchain-based trading platform can enable efficient automated transactions, but it can also convey a sense of security, privacy, transparency and community (Mengelkamp, Notheisen, Beer, Dauer, & Weinhardt, 2018).

2.2.2 Drivers and barriers for participation in P2P electricity trading

To ensure that prosumers' individual preferences, e.g. being financially, environmentally or socially driven, are acknowledged, a P2P electricity trading coordination system has to take this information into account. Additionally, this information can help to understand and predict prosumers' trading behaviour (Morstyn et al., 2018). The recent literature that has been undertaken into the preferences of prosumers regarding the way they want to trade and share self-produced electricity, is reviewed in this section in order to draw comparisons and identify potential extensions to these findings.

Mengelkamp et al. (2018) conducted a survey with German electricity customers to investigate how five pre-selected factors influence their motivation to take part in LEM. They found that community identity, technological interest and importance of green products have the biggest impact, while price consciousness and attitude towards regional products had no impact on the willingness to participate in LEM. Their concluding recommendations were to specifically promote LEM to consumers with interests in environmental issues, technological innovations and community values. In a follow-up study, Mengelkamp et al. (2019) used a survey based on a choice experiment investigating the impact of LEM characteristics for German households. They found economic aspects to be most important when deciding to participate in LEM. All other assessed aspects, which were the choice of supplier, input frequency, electricity source and data usage, are equally important and in sum as important as the investment and monthly costs. Costs were also identified as the predominant determinant for P2P electricity trading behaviour by Hahnel et al. (2020).

Reuter and Loock (2017) conducted an extensive survey covering many aspects of LEM with households in Germany, Spain, Norway and Switzerland and found that 79% were willing to participate in LEM with no significant differences across these countries. In terms of governance preferences of LEM, most participants endorsed the idea that cooperatives consisting of local or regional citizens initiate and govern the markets. Regarding drivers for participation in LEM, environmental aspects were found most important, followed by economic, then technological, then political and finally community aspects. They also found that across all countries, participants are more willing to sell excess electricity than sharing it without a financial transaction. When it comes to concerns, participants were most concerned about the security of energy supply and increased bureaucracy. Increasing coordination among neighbours and reduced data privacy were perceived as potential risks of LEM by fewer participants. Similar trends were found by Hackbarth and Löbbe (2020) in a study with Germany households, of which 74.5% felt generally open towards P2P electricity trading with 11% stating they would participate in it in the next two years. These forerunners are likely to be concerned about the environment, regionality and transparency, and they are rather motivated by shared generation and consumption than economic advantages. Furthermore, participants preferred services that were easy to implement and therefore more comfortable. The authors suggest that the communication promoting participation is both informative and emotionally framed, while emphasizing the transparency and environmental friendliness. Additionally, peer-effects like word-of-mouth may be used to increase awareness. They conclude that P2P electricity trading can be considered as a niche market for technologically interested consumers, who were willing to pay more than average market prices and are more likely to accept dynamic tariffs. Another driver was identified by Ecker et al. (2018) who focused the influence of autarky, i.e. independence of supply, on homeowners' willingness to exchange self-generated energy within a local energy network. They found that emphasizing autarky benefits increases the perceived value of self-generated energy and reduces the willingness to participate in P2P energy exchange.

Finally, Wilkinson et al. (2020) extended the current state of literature by setting up a trial P2P electricity trading project in Australia using a blockchain platform. They found that users who joined their platform were mostly financially stable households who were interested in social equity and transitioning to environmentally cleaner energy systems. Furthermore, they found that users were interested in learning more about innovative technology and to implement a new community-based electricity market to change the existing sector they were unsatisfied with. The authors add that this may imply that mainstream consumers are more difficult to be motivated to participate in P2P electricity trading.

2.2.3 Peer-to-peer returns

Receiving a return for the provided good or service is a key process in any transaction. Therefore, this research investigated the possibilities of compensation beyond monetary returns when electricity is traded within a community or with peers. Singh et al. (2018) explored P2P returns in off-grid RE systems in rural India by means of an ethnographic study. The authors identify three types of returns to be used in the transactions. *In-cash returns* in the form of the local currency based on set prices in order to make profit. *In-kind returns* of a non-cash form but still of monetary value, which could be profitable for the seller. And finally, *intangible returns* of a non-monetary form, which are unmeasured and unquantified social gestures. Singh et al. (2018) concluded that the three types of return are strongly dependent on the social relation of the two exchanging actors, while also being on a coexisting and dynamic spectrum, i.e. a returns-continuum, within the social sphere of economy.

2.3 Intention-behaviour gap

Research shows that intention alone does not necessarily lead to the corresponding behaviour, i.e. in this case the participation in a P2P electricity market. The intention–behaviour gap describes the discrepancies between an individual's intentions regarding their actual behaviours, which can be explained with too optimistic goals and missing abilities and resources to achieve these goals (Sheeran & Webb, 2016). Intentions are formed from both personal beliefs about the outcomes of acting (attitudes) and social pressure (norms) (Sheeran & Orbell, 1999). While survey results about renewable energy attitudes in Western countries show that typically 50-90% favour renewable energy, only a small percentage of the population uses renewable energy (Momsen & Stoerk, 2014). Values and attitudes of individuals were found to have a strong influence on renewable energy adoption intention (Claudy, Peterson, & O'Driscoll, 2013). A gap was also observed between individuals' self-reported knowledge, values, attitudes and believes and their actions regarding energy consumption, which may stem from people rarely being purely rational decision-makers and the human property of using mental shortcuts when deciding about complex, risky and uncertain issues (Frederiks, Stenner, & Hobman, 2015). To get from an intention to the adoption of renewable energy, Claudy et al. (2013) propose to provide additional reasons for adoption, reduce reasons against adoption and to encourage consumers to develop environmental values. Similar patterns can be expected for the intention versus the actual participation in P2P electricity trading. One should be aware of the intention-behaviour gap when interpreting the results from a survey with individuals and deriving practical recommendations on the basis of adoption predictions. The proposed survey method, i.e. the DCE, has potential to work around this bias, as it does not directly ask for participants' intentions, but implicitly investigates their preferences. This method is explained in detail in Chapter 3.

2.4 Conceptual framework

From the concepts reviewed in literature, the conceptual framework of this research was derived. A visual representation of this conceptional framework can be seen in Figure 2. The subject of investigation are prosumers in the Netherlands. Their socio-economic background, their characteristics in terms of the DER system, as well as their environmental, communal and technological attitude are expected to have an influence on their electricity trading preferences. These preferences can be classified into environmental, social, economic, and technological categories and are expected to influence prosumers' decisions about participating in either P2P electricity trading or in traditional electricity trading, where surplus in fed into the central grid. The concept of non-monetary compensation for trading surplus electricity is an additional point of interest of this research, and prosumers' attitude towards these may influence their trading preferences as well. The participation in P2P electricity trading is also expected to be influenced by external facilitators and barriers. Facilitators can overcome the intention-behaviour gap that is expected to exist between prosumers' preferences and their actual trading behaviour, while barriers may widen this gap. One actor that is proposed as facilitators of the establishment and adoption of P2P electricity trading are energy cooperatives, who play an important role in the Dutch energy transition and who are often early adopters of novel DER. Other facilitators and barriers will follow from the theoretical and practical implications that were derived from the survey's findings.

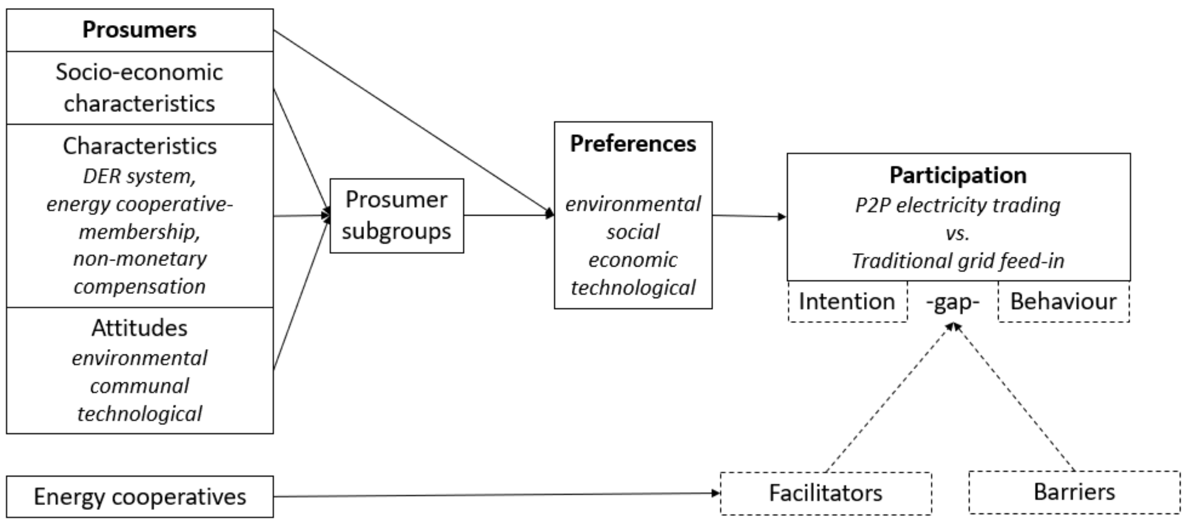

Figure 2. Conceptual framework showing the coherences of the researched variables with prosumers' preferences regarding P2P electricity exchange.

3 Methods

In this chapter, the applied methods are described in more detail. In Section 3.1 Design of the discrete choice experiment, the design of the DCE is specified, which was applied to elicit the participating prosumers' preferences for trading surplus electricity. In Section 3.2 Selection of attributes and attribute levels, the selection process of attributes and attribute levels for the DCE is explicated. In Section 3.3 Questionnaire structure and additional questions, the questionnaire structure of the survey is outlined and the additional questions that were asked in order to identify participant's characteristics as a prosumer and their attitudes towards the environment, their community and technologies are described. And finally, the data collection process is presented in Section 3.4 Data collection.

3.1 Design of the discrete choice experiment

3.1.1 Background DCE

As previously mentioned, this research will make use of a DCE, which is a widely applied method for analysing complex decision-making processes (Mangham et al., 2009). The method uses an attribute-based survey to measure preferences assuming that participants strive to maximise their utility through rational decision-making. Therefore, the basic principle underlying DCEs is an optimisation process in which individuals select a bundle of attributes which satisfies their needs and thereby reveals their personal preferences (Amaya-Amaya, Gerard, & Ryan, 2008). The method strives to simulate real-life decision-making processes in order to calculate preference scores which respondents assign to the selected attributes that define the product or service (Lüthi & Prässler, 2011).

The grounds for the theory and application of DCEs lie in choice modelling and can be traced back to Thurstone (1927), who in his work "A Law on Comparative Judgement" first described the random utility theory. The theory of random utility in economics was extended by the work of McFadden (1973) with the conditional logit model. The first application of choice experiments was in the forecasting of market demands (McFadden, 1986). A wide-spread commercial use of choice experiments appeared in the 1990s (Hill, 2017). In case of scientific research, especially health care scientists started making use of DCEs to measure perceived benefits of treatment options beyond health outcomes. Recent publications show that the application of DCEs (or similar choice-based surveying methods) has found increasing popularity in the field of energy transition research, to which this research can also be accounted to. DCEs were used to identify preferences for investing into renewable and non-renewable energy technologies (Kim, Park, & Lee, 2018; Ku & Yoo, 2010; Salm, Hille, & Wüstenhagen, 2016; van Rijnsoever, van Mossel, & Broecks, 2015), for micro-cogeneration products (Rommel & Sagebiel, 2017), for participating in renewable energy programmes (Boeri & Longo, 2017), for investing in environmentally friendly vehicles (Byun, Shin, & Lee, 2018), for investments in energy saving measures for buildings (Achtnicht & Madlener, 2014; Kwak, Yoo, & Kwak, 2010), for buying electricity from energy cooperatives (Sagebiel, Müller, & Rommel, 2014), and finally for participating in LEM and P2P electricity exchange (Hahnel et al., 2020; Mengelkamp et al., 2019).

As previously mentioned, DCEs are based on random utility theory and respondents are assumed to make choices to maximise their own utility. In the next paragraph, I will shortly describe the concept behind random utility theory to facilitate comprehending the statistical analysis of the DCE data that will follow later in this report (see Chapter 4 Results). Firstly, a utility function U_i as seen in Eq. (1) can be used to represent each alternative i.

$$U_i = \beta A_i + \varepsilon_i = V_i + \varepsilon_i \qquad (1)$$

A_i is a vector of all the attribute levels in this alternative $i(a_{1i,}a_{2i}, \ldots)$ and β is a vector of associated parameters which can be interpreted as utility weights. The component ε_i represents a random component capturing all effects on the utility that cannot be described by observed variables. The observable part of the utility $A_i\beta$ is denoted as V_i (Rommel & Sagebiel, 2017). According to McFadden's (1973) conditional logit model, the probability to choose alternative j out of n alternatives conditional on V_i is described by Eq. (2), when ε_i are identically and independently distributed.

$$Prob(j) = \frac{expV_j}{\sum_{i=1}^{n} expV_i} \qquad (2)$$

Eq. 2 outputs probabilities between 0 and 1 and assumes that the marginal effect of attribute changes on the choice probability are not constant. This gives a more realistic interpretation of consumer behaviour. The parameters β can be estimated by using the maximum likelihood method which returns values where the estimated probabilities are closest to the actual choices. The utility weights β cannot necessarily be interpreted, because utility is a relative measure. Nevertheless, ratios of the utility weight can be interpreted as the marginal rate of substitution the consumer would be willing to give up of one attribute in exchange for an increase in another attribute (Rommel & Sagebiel, 2017).

3.1.2 Software

The survey was designed and implemented using the software tool Lighthouse Studio 9.8.1 by Sawtooth (Sawtooth Software, 2020). The tool is one of the market leaders in choice-based conjoint (CBC) analyses and offers a variety of question and experiment designs to investigate individual preferences. In the earlier days these techniques were commonly used in market research to identify and compare traditional market offerings of products and surveys. Lighthouse Studio is now increasingly used by researchers of various scientific fields as it has proven itself useful for investigating complex decision-making processes in individuals. For the DCE used in the survey, the experiment settings for the traditional CBC analysis was chosen, which included all features necessary to design the DCE. Apart from choosing the general design for the DCE, several additional design decisions were taken which will be further elaborated in the following sections.

3.1.3 Design of attributes and levels

For the design of the DCE, several key attributes are selected to describe the different alternatives of electricity trading systems. Each attribute has several levels, which define the attributes possible values. Although there is no limit to key attributes, most DCEs contain fewer than ten to not overwhelm participants (DeShazo & Fermon, 2002). Overall, six attributes were chosen, and three levels were assigned to each attribute. The levels were chosen such that one describes a trading process with the traditional grid, one means to reflect a P2P trading system, and one describes an intermediate state reflecting indifference. The first selection of attributes was made from reviewing the relevant literature. To identify the attributes and attribute levels most relevant for answering the research question experts and prosumers were interviewed. A detailed description of the selection procedure of attributes and corresponding levels will follow in Section 3.2 Selection of attributes and attribute levels.

3.1.4 Design of choice sets

The choice sets present participants with three alternatives – each consisting of the selected attributes with varying attribute levels. Figure 3 gives a generic representation of a choice set. Most DCEs do not contain more than sixteen choice sets to remain below the "boredom threshold", which describes the point at which questionnaire participants become fatigued from being asked too many questions (Amaya-Amaya et al., 2008; Hanson, McPake, Nakamba, & Archard, 2005). Therefore, a selection of alternatives presented in the questionnaire has to be made, because for example a DCE consisting of five attributes with three level each leads to 243 possible alternatives. As the survey in this study does include several questions besides the DCE, the decision was made to include only twelve choice tasks. From literature and pre-testing the choice experiment, it became evident that twelve choice tasks can be expected to yield significant and reliable results in the considered P2P electricity exchange application (Johnson & Orme, 1996), while ensuring that participants remain focused and interested in answering the survey.

	Alternative 1	Alternative 2	Alternative 3
Attribute A	Level_A_x	Level_A_y	Level_A_x
Attribute B	Level_B_z	Level_B_y	Level_B_x
Attribute C	Level_C_y	Level_C_y	Level_C_z
…	…	…	…
Which alternative do you choose?			

Figure 3. Generic choice set design for a DCE.

Of the twelve choice sets nine are designed to later analyse participants' preferences and three are designed as so-called holdout tasks. The nine choice sets were designed making use of the *Balanced Overlap* function in the Lighthouse Studio software tool. The *Balanced Overlap* function can generate a randomised design, which results in a large number of unique choice sets so that each participant received a unique DCE. This has the advantage of generating significantly more data than in a fixed design where every participant would receive the same choice sets. Nonetheless, the *Balanced Overlap* is not purely random, but follows several design principles in order to receive choice sets whose results are sufficient to analyse. To a certain extent, the choice sets follow the principle of orthogonality, which results in attribute levels being "chosen independently of other attribute levels, so that each attribute level's effect (utility) may be measured independently of all other effects" (Orme, 2010). Furthermore, the attribute levels are balanced which means that each level of an attribute is shown approximately an equal number of times. Still, the design allows for a modest amount overlap of levels within the same choice tasks to prevent that participants keep choosing alternatives because of a critical "must-have" level and to investigate interactions between different attributes (Orme, 2010).

The remaining three choice sets are so-called holdout tasks. These choice sets are fixed and thereby every participant received them in the same position within the choice experiment. It is recommended to include these fixed holdout tasks for three reasons. Firstly, they can serve as a validity measure (Janssen, Marshall, Hauber, & Bridges, 2017). Two of the holdout tasks are identical in order to control whether participants have read and comprehended the presented choice tasks. Still, it can be expected that there will be a significant amount of discrepancies as responding to choice tasks is complex and as participants' may change their answering behaviour throughout the experiment

(Janssen et al., 2017). Secondly, it is recommended to include a choice set that reflects reality. In this study's case, this is a choice set with an alternative that consists of all attribute levels describing the trading with the central grid, an alternative with levels describing a P2P trading scheme, and an alternative consisting of the intermediate levels to reflect indifference (Orme, 2014). This "reality choice set" is combined with the "identical choice set" and appears therefore twice. Thirdly, a fixed choice set was included to assess convergent validity, which measures to which extent DCE results are consistent with another method measuring a similar construct. The three chosen constructs are economic, community and environmental preferences. Attributes that do not reflect any of these constructs were kept constant at the intermediate level. Results from this holdout task were compared to the results from the attitude questions and used to further identify interest groups (Janssen et al., 2017).

Another decision made considered the amount alternative options in a choice task. According to literature up to four alternatives can be taken up by participants. Although including only two alternatives is done by some researchers in practice, it may be insufficient for receiving analysable and interpretable results (Orme, 2010). This DCE used three alternatives which corresponded with the amount of levels in each attribute and as three alternative options have been proven to generate sufficient data for analyses, while also being processed well by participants (Orme, 2010). Some DCEs include a "choose none" option next to the alternatives. Thereby participants have the option to opt-out and not pick any of the presented alternatives. This is mainly done to reflect the reality of the free market where consumers can decide not to buy a product or service (Orme, 2010). In the case of selling surplus electricity, it was assumed that prosumers who already made significant investments for a DER will certainly make use of trading systems. Therefore, the DCE applied in the survey does not give a "choose none" option. Furthermore, the order of the attributes was not randomised. All participants received choice sets in which the attributes were given in the same order to avoid confusion and to avoid the position of an attribute influencing results across participants.

3.2 Selection of attributes and attribute levels

3.2.1 Selection from literature and operationalisation

Attributes should reflect the characteristics of the investigated decision that are expected to affect respondents' choices the most. At the same time attributes should be policy relevant (Mangham et al., 2009). The first selection of attributes was made by going through relevant literature on LEM and P2P electricity trading (Hackbarth & Löbbe, 2020; Mengelkamp et al., 2019; Mengelkamp et al., 2018). Other attributes were added using the researcher's and the project partners' prior knowledge and experience on the topic.

The preliminary selected attributes (see Table 1) are all deemed appropriate to investigate the preferences of prosumers regarding electricity exchange. They cover social, economic, technological and environmental sustainability aspects that are related to renewable DER and electricity trading in order to incorporate the multiple dimensions that prosumers may consider when making a decision regarding the use of surplus electricity. Thereby, a participant repeatedly choosing beneficial attribute levels of one aspect over others can be interpreted as the participant preferring that aspect. The following paragraphs will present how the aforementioned aspects were operationalised by pre-selecting attributes from literature. Furthermore, the corresponding levels are explained, and their scientific relevance is highlighted.

Table 1. Preselected attributes from the relevant literature on P2P electricity trading and the researcher's and the project partners' prior knowledge and experience on the topic.

	Attribute	*Category*	*Levels*		
1	CO_2 emissions	Environmental	Low	Medium	High
2	Share of renewables	Environmental	25%	50%-75%	100%
3	Location of electricity trading partner	Social	Local	Member of energy community (local or non-local)	Non-Local
4	Social connection with electricity trading partner	Social	None (anonymous)	Direct (neighbour)	Close (friends and family)
5	Selling price	Economic	10 €ct/kWh	15 €ct/kWh	20 €ct/kWh
6	Additional effort (time)	Economic	0 h/month	2 h/month	4 h/month
7	Improved efficiency	Technological	5%	15%	30%
8	Reliability of supply	Technological	Low	Medium	High
9	Self-sufficiency	Technological/ Social	Low	Medium	High

Environmental sustainability aspect.

The desire or awareness for making changes to live a more sustainable lifestyle is a key driver for individuals that decide to install renewable DER (Palm, 2018). Participation in LEM including the opportunity to exchange and trade electricity on a P2P basis does on the one hand often incorporate renewable DER and can on the other hand be seen as someone having an equally or even greater interest in sustainability. In fact, Mengelkamp et al. (2018) found that the importance of green products is a main influencing factor for LEM participation. The aspect of environmental sustainability was operationalised in the two following attributes.

1. CO_2 emissions. A co-benefit of P2P electricity exchange is that most underlying energy generating technologies are using renewable energy sources, e.g. PV panels, and are therefore contributing to CO_2 reduction (Rommel & Sagebiel, 2017). The prevailing energy mix in the Netherlands on the other hand consists mostly of fossil resources resulting in high CO_2 emissions for electricity generation (IEA, 2020).

2. Share of renewables. The share of renewables in the electricity mix is similar to the attribute CO_2 emissions, as a higher share currently implies a preference for locally produced renewable electricity, while a lower share reflects electricity from the Dutch central grid.

Social aspect.

Participation in LEM and P2P trading seems to be positively influenced by someone's sense of community identity (Mengelkamp et al., 2018). Furthermore, community energy projects are on the rise and many see them as an effective approach to a fair renewable energy transition (Seyfang, Park, & Smith, 2013). This indicates that social aspects will play a role in prosumers decision making process with whom, where or how they trade surplus electricity. Two attributes have been pre-selected to operationalise the social aspect of P2P trading.

3. Location of electricity trading partners. Being able to decide about the location of the peer the electricity is exchanged with is a distinctive feature of P2P trading. Mengelkamp et al. (2018) identified regionally oriented consumers to be more likely to participate in LEM. The decision for a local peer, someone who is in the same energy community or a non-local peer is therefore a direct indicator for determining the participant's spatial preference regarding electricity exchange.

4. Social connection with electricity trading partners. Prosumers being able to decide whom to share their electricity with is another characteristic feature of an electricity trading platform designed for P2P exchange. With this attribute it can be assessed to what extent the participant prefers to know the household they provide their surplus electricity to. The preference for the social connection may also reflect the participant's preferred return. Singh et al. (2018) found that the closer the connection of energy providers was with the consumer, the more often the accepted returns were in-kind or intangible.

Economic aspect.

Several studies found economic aspects to be the most important factor in decision-making processes regarding electricity trading (Bayram et al., 2014; Hackbarth & Löbbe, 2020; Mengelkamp et al., 2019). The following two attributes were chosen to reflect the economic aspect within the DCE.

5. Selling price. Participation in LEM enables prosumers to optimally utilise the renewable DER and to thereby optimise electricity procurement costs as well as returns, as losses can be minimised and demand may be reduced (Jogunola et al., 2017). Under the current net-metering scheme active in the Netherlands, prosumers can sell to and purchase from the grid for the same electricity tariff. However, when the net-metering scheme ends, the compensation for feeding into the grid will be reduced and the financial benefits of P2P electricity trading will increase in comparison. The chosen levels for the electricity tariff therefore reflect the current average grid tariff in the Netherlands being 20 €ct/kWh as upper level (Eurostat, 2019), an assumption of 10 €ct/kWh for the future FiT based on the current tariff in Germany (Bundesnetzagentur, 2020), and a medium value of 15 €ct/kWh for the selling price in P2P trading.

6. Additional effort (time). To a certain extent, time can be seen as a scarce resource that households treat similarly to money (Becker, 1965; Heckman, 2015). Feeding the surplus electricity into the central electricity grid under a standard contract entails little to none effort on a monthly basis. Participation in LEM requires regular interaction with an information system (Mengelkamp et al., 2018). Although the time needed to manage a P2P electricity exchange can be reduced by well-designed algorithms, it includes some time investment and therefore entails additional effort.

Technological aspect.

Mengelkamp et al. (2018) found that technology affinity positively affects peoples' willingness to participate in LEM. The underlying technical systems of P2P electricity trading have several implications, which resulted in pre-selecting the following three attributes to operationalise the technological aspect.

7. Improved efficiency. When appropriately managed local (smart) electricity grids have the potential to improve grid efficiency and to utilise more of the energy that is generated by a renewable DER, thereby reducing energy losses (Bayram et al., 2014; Morstyn et al., 2018) and the required imports from a central grid (van Leeuwen et al., 2020). Enabling participants to choose between low, medium and high efficiency improvements may reveal their preference for either a highly efficient micro-managed local electricity grid or a centralised grid.

8. Reliability of supply. Since most electricity generating technologies adopted by prosumers use variable renewable energy, their reliability is limited. Although an efficient smart grid can enhance the energy security, one must assume that when compared to a large grid operator who has several mechanisms in place to avoid electricity shortages, P2P electricity exchange bears more risks regarding the reliability of supply (Parag & Sovacool, 2016).

9. Self-sufficiency. P2P trading is a form of self-organisation that entails a certain level of autonomy from private or state-owned energy suppliers and grid operators, while also providing the possibility to be an active part of the energy transition (Morstyn et al., 2018). At the same time, the blockchain technology behind the electricity trading platform ensure that data is kept private and protected (Buth et al., 2019). These two aspects can be summarised a being self-sufficient.

3.2.2 Attribute refinement through interviews

In total nine interviews were conducted to refine and select the attributes. Figure 4 visualises the final selected attributes after the refinement through the interviews. The interview partners were found through personal contacts of the project partners and posts on social media. Five interviewees were prosumers, and all of them were either active in an energy cooperative or worked in the field of RE and environmental consulting. Of the remaining four interviewees, two work as consultants in the energy transition and two are academic experts in the field of LEM and energy cooperatives. Eight interviews were conducted via video calls and recorded, while one interview was held in-person. Appendix A.1 Interview guide for prosumers and Appendix A.2 Key take-aways from the interviews gives an overview over the interview partners and their mentioned key points.

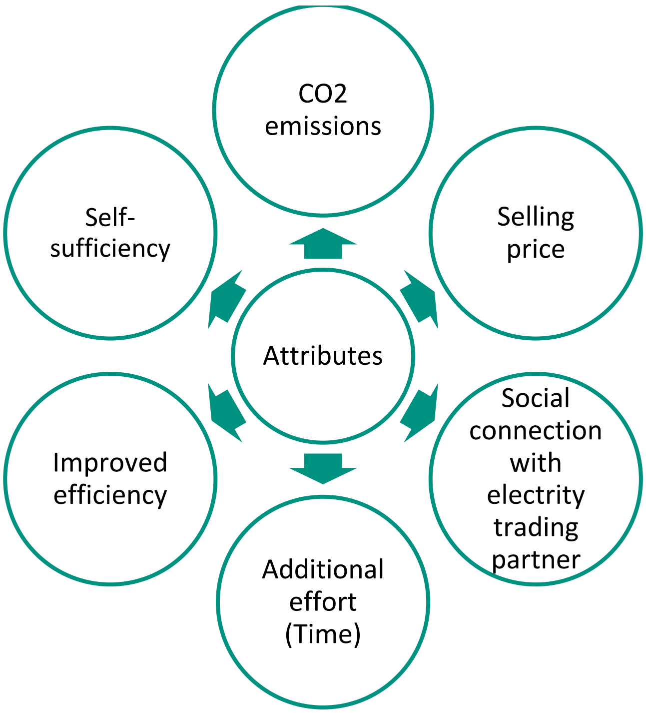

Figure 4. Final selected attributes included in the DCE on P2P electricity trading.

Table 2 shows how often the attributes were mentioned and whether interviewees valued them as important, unimportant or refrained after they were confronted with them. The two academic experts are left out of this analysis as they were primarily interviewed about the fit of the method for the investigated research questions, and to confirm the chosen attributes and levels.

Table 2. Results of the attribute refinement through the seven conducted interviews, with the ultimately selected attributes in bold. To be read as # out of seven interviewees.

	Attribute	*Mentioned by themselves*	*Valued important*	*Valued not important*	*Not mentioned or reacted to*
1	**CO_2 emissions**	5	7	-	-
2	Share of renewables	5	7	-	-
3	Location of electricity trading partner	-	-	3	4
4	**Social connection with electricity trading partner**	-	3	2	2
5	**Selling price**	7	7	-	-
6	**Additional effort (time)**	4	6	-	1
7	**Improved efficiency**	-	3	-	4
8	Reliability of supply	-	-	3	4
9	**Self-sufficiency**	5	4	2	1

All included interviewees mentioned that the economic aspect would play a major role in both deciding whether to install a renewable DER and how to handle the surplus electricity. Therefore, the attribute *Selling price* was included into the final DCE design. A majority mentioned that a P2P trading system would have to be convenient in terms of usage and that much additional effort would probably decrease the acceptance of P2P trading. Therefore, the attribute *Additional effort (time)* was included into the final DCE. All prosumers in one or the other way stated that living a more sustainable lifestyle was an important factor in the decision process of installing a renewable DER. The sustainability aspect can be included through the two attributes *CO_2 emissions* and *Share of renewables*. To avoid overlap and because it was perceived as being easier to comprehend, the attribute *CO_2 emissions* was included in the final attribute list of the DCE. The responses on increased self-sufficiency were mixed. Some interviewees mentioned it as an important aspect in regard to future insecurities of the electricity supply, while others emphasised that they will remain reliant on the larger grid and providers and the self-sufficiency is highly unlike in a country like the Netherlands. Nevertheless, the attribute *Self-sufficiency* was included into the final DCE as it is a characterising trait of LEM and an important decision factor for many prosumers. The possibility of choosing electricity partners was seen as an interesting aspect by many interview partners, that most were unaware of. Some mentioned they would be willing to give surplus electricity to local institutions like schools or to friends for a lower price or no charge. Other interviewees stated that they do not see additional value in choosing their electricity trading partners. Although none of the interviewees mentioned the aspect by themselves, the research wants to focus on the aspect of the social connection between electricity trading partners and therefore the attribute *Social connection with electricity trading partner* was included into the final DCE design. The related attribute *Location of electricity trading partner* was excluded due to overlap and as it was perceived as less important. The same goes for the attribute *Improved efficiency.* Although it was not mentioned directly by prosumers, it was included in the final DCE. It can be assumed that the technicalities of a P2P trading scheme are unknown by the interviewees. Yet, when they were confronted with the information that P2P can have the benefit of improved efficiency, all stated that this can be an influential factor for participation. The attribute *Data privacy* was excluded from the final DCE design as the majority of interviewees did not deem it as an important factor for their personal decision in electricity trading. Likewise, the pre-selected attribute *Reliability of supply* was excluded as it was neither mentioned nor valued as an important feature of P2P trading by any interviewees. In fact, when mentioned, many interviewees highlighted their trust in the Dutch electricity supply network and emphasised that they are not concerned about energy shortages.

3.3 Questionnaire structure and additional questions

The full English version of the questionnaire can be reviewed in Appendix B: Full questionnaire. The questionnaire that was presented to participants was translated into Dutch prior to fielding. The questionnaire started with an introduction. First, the purpose of the survey was explained. Next, respondents were made aware that they can only partake in the survey if they own a renewable DER. Next, it was stated that all data is collected anonymously, will be kept confidential and will not be used for commercial activities. Participants were provided with the researcher's contact details in case they had any recommendations or questions. The very first question was a screening question which asked participants whether they own a renewable DER. A participant replying with "no" was terminated from the survey as they were not eligible to partake. The first question section covered questions that provided insight into the participants' characteristics regarding them being prosumers. The second section contained the DCE. The third survey section consisted of six statement questions about the participant's attitude towards the environment, their local community, and technology. The fourth and last section of the survey contained questions regarding the respondent's socio-economic characteristics. An overview of the questionnaire structure is visualised in Figure 5.

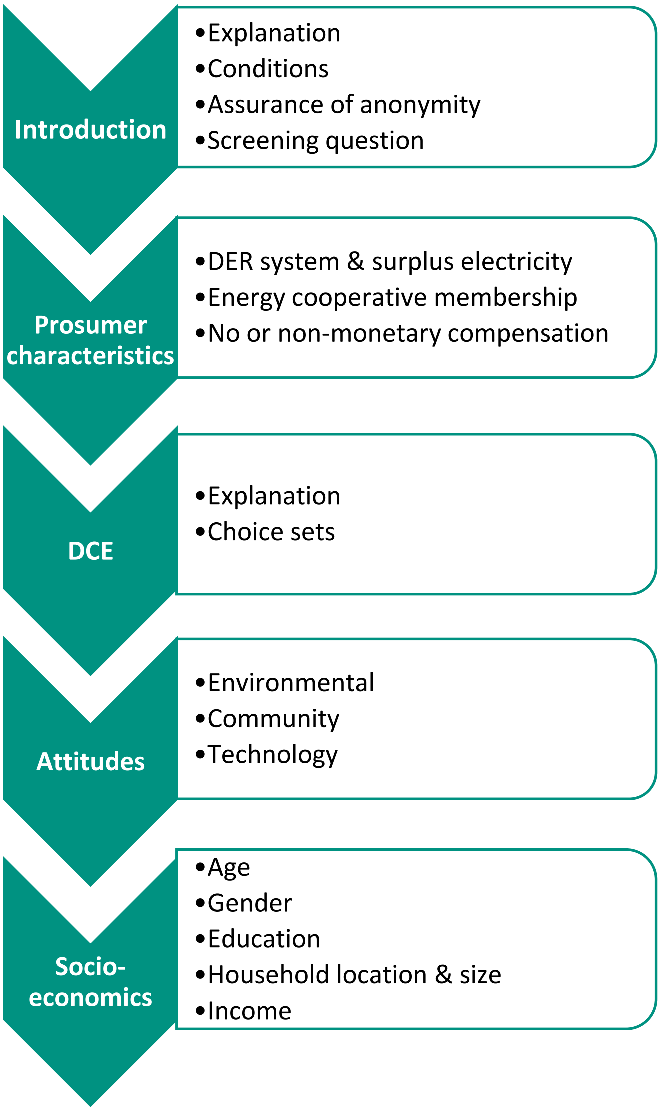

Figure 5. Questionnaire structure.

3.3.1 Design of prosumer characteristics questions

To receive data about the current status of the Dutch prosumer community regarding their renewable DER system, the current use of surplus electricity and their membership in an energy cooperative, eight questions were asked in this section. The first questions asked for the reasons for installing the DER system giving five response options and the possibility to write down a response in open form. In the next two questions, participants were asked whether they know how much surplus electricity they produced, and they were asked to indicate the amount in case they did know. The fourth question asked for the reasons for choosing their current electricity provider, giving six response options and again the possibility to write additional reasons in open form. The next question asked whether the respondent was a member of an energy cooperative or community, also giving a definition of theses. A respondent answering with yes was redirected to a question asking for the motivations to join and gave seven options with an additional option to write down additional different reasons. The final two questions regarded the compensation for giving surplus electricity. In particular, respondents were asked whether they would give away surplus electricity for free and whether they would be willing to give surplus electricity away for an indirect monetary compensation. For both questions, six options for exchange partners were provided and also the option “no”.

3.3.2 Design of environmental, community and technology attitudes questions

In this survey section, six statements were derived from literature that assessed the three constructs environmental, community or technological attitudes of participants. In this context a construct is a variable that operationalises each one of these three attitudes. Thereby, it is possible to explore a possible link between environmental awareness, feelings towards their local community and interest in technologies and preferences in P2P electricity exchange. The statements were to be answered on a 5-point Likert scale which ranged from 1 (strongly disagree) to 5 (strongly agree).

Environmental awareness. The two statements about the participant’s environmental attitude were taken from Hackbarth and Löbbe (2020) who derived them from a survey that investigated environmental awareness in Germany (Kuckartz, 2000). The two chosen statements are “I am concerned about human behaviour and its impact om the climate and the environment” and “I always pay attention to ecological criteria when buying products and services”.

Community identity. The next two statements concerned participants’ attitude towards their local community. The first one reads “I feel a strong identification with my local community” and was taken from Mengelkamp et al. (2019). The second one was “There are many people in my local community whom I think of as friends” and was constructed by Kalkbrenner and Roosen (2016) and adopted from van Vugt (2016)

Technological affinity. The two statements to measure technological affinity were gathered from survey constructed by Karrer, Glaser, Clemens, and Bruder (2009) and are “Learning how to use a technological device is easy for me” and “I enjoy exploring new technologies”.

3.3.3 Design of socio-economic questions

The final section of the survey was used to ask participants about their socio-economic background. This allows an examination of the effects of the socio-economic background on individual preferences. In particular, the participants were asked to indicate their age, gender, and education. Furthermore, they were asked in which setting, i.e. large city, medium city, small city or village, their household is located and how many people live in their household. Finally, they were asked to indicate their household's average yearly net income.

3.4 Data collection

3.4.1 Sample

The final version of the questionnaire was distributed among Dutch prosumers. Considering the European Commission's (EC) projections about the number of residential PV prosumer in the Netherlands being about 405,000 in 2020 (European Commission, 2017), an appropriate sample size should include at least 384 participants (Krejcie & Morgan, 1970). To achieve this sample size the questionnaire was sent out in electronic form. In case of a DCE, sample sizes may differ as a lot of data can be obtained using a random design strategy.

The sample size used in DCEs varies significantly across studies. Bekker-Grob, Donkers, Jonker, and Stolk (2015) reviewed DCE studies performed in the healthcare sector and found that 32% had sample sizes below 100 and 31% acquired sample sizes over 600. A proposed rule of thumb to calculate the minimum required sample size by using Eq. 3 (Orme, 2019).

$$N > \frac{500c}{(t*a)} \qquad (3)$$

In the formula c equals the largest number of levels for any of the attributes, t the number of choice tasks and a is the number of alternatives. The number 500 represents the least amount of times each attribute level has to be represented in the DCE to achieve sufficient stability in estimates. In this study c equals 3, t is 9 (without holdout tasks), and a is 3. Therefore, in this case the minimum sample size required is 56 (round up from 55.56). But there have been concerns that this rule-of-thumb is inappropriate and yields too small sample sizes. Orme (2019) suggests increasing the threshold for level occurrences from 500 to 1000, which would in our case lead to a doubling of the sample size, i.e. 112. Additionally, he recommends having at least 200 respondents per group if the researchers want to compare different groups and receive significant differences. If comparing sub-groups is not an objective of the research, Orme (2019) still recommends at least 300 respondents.

3.4.2 Validation and testing of the survey

In order to validate the survey prior to fielding, it was tested in three steps. Firstly, the survey was sent to several academic and industry experts to receive feedback. Consulting a panel of experts is a common technique to check the content validity of a questionnaire (Grant & Davis, 1997). The expert panel consisted of three researchers and two professionals of the field. One of the academic experts is the supervisor of this thesis, who initiated the project. The second is an experienced researcher in the field of energy cooperatives and their impact on collective action among households. The third academic expert consulted has conducted several research projects on local energy markets, and also has experience regarding the application of choice experiments in this field. Both professional experts were project partners, therefore having extensive insights into the objectives. All experts, but the third academic expert, were regularly updated about the progress of the questionnaire and gave feedback on several occasions via email, video conference or personal meetings. The third academic expert was interviewed once via video conference. The questionnaire was updated several times after receiving feedback before it was translated into Dutch.

Secondly, the survey was sent to three Dutch speaking individuals, who had no knowledge about the research, to test for the questionnaire's comprehensiveness and the approximate time to complete it. All consulted individuals responded that they had no issue in understanding the questionnaire. The average time to complete the questionnaire was 13:56 (mean value of 12:34 min, 16:02, and 13:11 min). Ideally, the sample for this validity assessment would have been bigger. Yet, due to time constraints and the thorough expert validation progress, the decision was made to not consult more individuals.

Finally, the DCE design was tested using the incorporated testing services of the Sawtooth Lighthouse Studio software (Orme, 2010). This test uses 300 automatically computed "dummy" respondent answers and standard errors. Sawtooth suggests that the standard errors within each attribute should be roughly equivalent, for main effects no larger than about 0.05, and for interaction effects no larger than about 0.10 (Orme, 2010). This is the case for the tested DCE design.

3.4.3 Fielding

The link to the online survey was distributed through the network of the project partners via email and social media in order to reach as many members of the target group as possible. Via email, over 25 organizations and individuals were approached which are active in fields related to RE projects or energy cooperatives in the Netherlands. Furthermore, the link was posted in Dutch Facebook communities of prosumers with a total of over 4,000 members. Next to that, the link was shared multiple times on the social media platform Twitter by several account holders. The exact amount of people receiving the link is difficult to provide due to the nature of the fielding process. Besides, it must be assumed that many individuals receiving the link are not members of the target group, yet these were identified and terminated with the first question of the survey. The fielding took place over seven weeks from the 14th of April until the 1st of June.

4 Results

4.1 Process of results analyses

The processing and analysis of the data gathered with the questionnaire consists of multiple steps that were performed by using Microsoft Excel and the analysis tool included in the software Lighthouse Studio 9.8.1 by Sawtooth, which was also used to design and host the survey (Sawtooth Software, 2020).

Step 1. The DCE results were analysed using Lighthouse Studio. The software provides all function necessary to perform the most common analyses for DCE, including the counting analysis and Hierarchical Bayes analysis used in this research. The goal of these analyses is to obtain the utility value and the importance scores of the attributes, thereby revealing the individuals' relative preferences (Amaya-Amaya et al., 2008; Hauber et al., 2016).

Step 2. The questions regarding participants' prosumer and socio-economic characteristics were analysed to obtain the percentages that responses were chosen The statements about environmental, community, and technological attitudes were analysed using statistical parameters, i.e. the means, standard deviations, Pearson's correlations, and Cronbach's alphas.

Step 3. Using the results obtained from Step 2, several subgroups were identified and the DCE analysis was repeated for these in order to gain insights into potential differences in between these subgroups.

4.1.1 DCE: Counting analysis

Performing a counting analysis on the data obtained from the DCE is the simplest form of assessing relative impacts of each attribute level, solely counting the times it was chosen over other attribute levels. Because in this DCE design all attribute levels have the same likelihood of occurring with each level of every other attribute, their impact can be assessed by simply counting the proportion of times that an option containing the attribute level is chosen. This cannot only be done for individual effect of levels, but also for joint effects, i.e. the occurrence of an attribute level together with another attribute level. The counting analysis provides an easy way to summarise the choice data, yet it can be subject to biases, when some attribute levels occur more often than others. In particular, this may be the case when the sample size is rather small. Therefore, it is recommended to perform additional data analyses that were developed to work around this bias such as the Hierarchical Bayes analysis describe in the next sub-section (Hill, 2017).

4.1.2 DCE: Hierarchical Bayes analysis

Today, hierarchical Bayes (HB) is the most commonly used method of analysis for data from conjoint studies (Rossi & Allenby, 2003). According to Johnson (2000) HB considers conditional probabilities, reflecting the probability of an outcome that is dependent on another "prior probability". This "prior probability" is also called the marginal probability and it is the probability of an event X. The "joint probability" is the likelihood of two events X and Y occurring together. There are also "posterior" probabilities that are assigned after seeing the data. From this the "conditional probability" can be calculated as the likelihood of the event X occurring when event Y has occurred before using Eq. 4.

$$P(X|Y) = \frac{P(X,Y)}{P(Y)} \qquad (4)$$

From this the “Bayes’ Rule” as seen in Eq. 5 can be derived.

$$P(X|Y) = \frac{P(Y,X)*P(X)}{P(Y)} \qquad (5)$$

This allows to compute the conditional probability of X given Y, when the conditional probability of Y given X and the two marginal probabilities of X and Y are known. As the likelihood of Y is not a subject of interest, it is regarded as constant in practical applications. This allows to express the Bayes rule in the form of Eq. 6.

$$P(X|Y) \propto P(Y|X) * P(X) \qquad (6)$$

Equation 6 relects that the posterior probabilities are proportional to the likelihood, i.e. the conditional probability, times the prior probability. Thereby, Bayesian analysis provides a way to update estimates of probabilities, allowing to obtain a posterior estimate that combines the prior information with information obtained from the data.

“Part-worth utilities measure the contribution of attribute levels to the overall utility, i.e. the influence of a change of the respective variable on the” prosumers likelihood to participate in a specific type of electricity trading (Lüthi & Prässler, 2011). The hierarchical Bayes (HB) estimation model can be used to calculate average part-worth utilities from individual part-worth utilities of each respondent. Compared to other methods like the standard multinomial logit (McFadden, 1986), the calculation of individual utilities in HB enables the assessment of heterogeneity between prosumer groups (Lüthi & Prässler, 2011). The HB model is described as “hierarchical” because it has two levels:

- At the higher level, individuals’ part-worth utilities, are described by a multivariate normal distribution, and are thereby considered as members of a population of similar individuals (Orme, 2010).
- At the lower level, it is assumed that probabilities of choosing a particular alternative, given the individuals’ part-worth utilities, are determined by a linear regression model (Orme, 2010).

The software used for the calculations assumes the differences in predicted and actual choices are distributed normally and independently of one another. Then, several thousand iterations are performed to adjust each respondent’s utilities to reflect the optimal mix of individual choices and sample averages (Howell, 2009). Because part-worth utilities are interval data which were randomly scaled to an additive constant within each attribute, it is not possible to compare utility values between different attributes. Therefore, part-worth utilities are zero-centred within each attribute and the sum of the average differences between best and worst levels across all attributes is equal to the number of attributes times a hundred (Orme, 2010). Thereby, differences between attribute levels can be compared. Finally, the importance scores of each attribute can be calculated by taking the range of the attributes’ utility values, i.e. the highest and the lowest part-worth utility of each attribute (Lüthi & Prässler, 2011). Here, a bigger range means that the attribute is deemed to have higher importance.

4.1.3 Prosumer characteristics and attitudes analysis

The analysis of the prosumer characteristics serves the purpose of receiving additional data on Dutch prosumers and to identify different prosumer groups. The results to these questions were summarised and presented in terms of the percentages that indicate how many respondents out of the entire sample chose the respective response. Additionally, the open answer questions are grouped and reported.

The statements regarding the constructs environmental, community and technology attitudes were first analysed by calculating means and standard deviation. Then, the two statements belonging to one construct are joint, the new means and standard deviations were calculated, and the constructs' Cronbach Alpha's were assessed to receive a measure for internal consistency of the statements within the construct. Cronbach's Alpha indicates how well the two selected statements are suited to measure the same construct. Here it must be noted that two-item scales are problematic, and researchers argue whether Cronbach's Alphas or Pearson's correlation coefficient are suitable to test their reliability (Eisinga, Grotenhuis, & Pelzer, 2013). Additionally, these results were used to identify several subgroups and to compare utility and importance scores received from the DCE analysis for these subgroups in order compare different prosumer groups' trading preferences.

The socio-economic characteristics of the sample were analysed statistically to provide results in terms of ratios. Again, the results were used to form subgroups, e.g. by age or household net income, to investigate whether these parameters influence prosumers' preferences regarding electricity trading.

4.2 DCE analysis

4.2.1 Final sample

To ensure that only participants who gave valid responses are included in the results analysis, speeders were removed. Participants were classified as speeders if they took less than 50% of the median time to complete the survey. The median time was 9:58 minutes and therefore respondents taking under 4:48 minutes were excluded. Of the 90 completed surveys, twelve respondents were terminated because they indicated that they did not have a renewable DER. Of the remaining 78 respondents, four were identified as speeders and excluded. Therefore 74 respondents were included in the final sample for the analysis.

4.2.2 Analysis of holdout tasks for validity and first indications

The three included holdout tasks were analysed as an indication for the validity of the results. Additionally, they give some first indications for participants trading preferences. The results of this analysis are summarised in Table 3. Firstly, the HIT rate was calculated from the three holdout tasks. The HIT rate is a measure to assess how well the modelled individual utilities predict individual responses. The computed utilities of each individual are compared to the respondents' choices in the three holdout tasks and then the percentage of how often the utilities predicted the choice correctly was calculated. The HIT rate was identified to be at 70.27%, which indicates that the model predicts respondents' choices well (Orme, 2009).

The first and third holdout task were identical to test the test-retest reliability. 60 of the 74 included respondents, i.e. 81.1%, chose both of the identical choice tasks that appeared in the third and the twelfth position of the DCE. This does not necessarily mean that the remaining 18.9% did not pay attention when doing the choice experiment. Yet, this is a good indication that the majority of respondents paid good attention when they chose alternatives and therefore for the validity and usefulness of the results.

The second use of the two fixed identical holdout tasks was to include alternatives that reflect reality. In this case, these were alternatives that consisted of attributes describing P2P trading, feeding surplus electricity into the grid under the net metering scheme (thereby indirectly supporting the Dutch electricity mix with high CO_2 emissions), and an indifferent case. 61.7% of respondents chose the alternative that described the proposed P2P trading scheme, 21.7% chose the alternative that described a system where one feeds surplus into the large grid, and 16.7% chose a scenario that consisted of the medium attribute levels indicating some sort of indifference.

The third holdout task was used for an indication of whether the respondent focuses on economic (Selling price: 20 €ct/kWh), social (Social connection: close) or environmental (CO_2 emissions: low) advantages in an electricity trading scheme, while all the other attribute levels are kept on the medium level. 58.1% of the respondents chose the environmental alternative, 23% the economic alternative and 18.9% the social alternative. This may be seen as a direct way of asking for analysing prosumers' preferences. Yet, the preliminary results should be used carefully, as preferences are proven to be better assessed in an indirect way by using utility values.

Table 3. Analysis of fixed holdout tasks

Holdout Tasks		*N*	*In %*
HIT rate of all holdout tasks combined		74	70.27
Identical Tasks	Chosen	60	81.1
	Not chosen	14	18.9
Reality Tasks*	P2P	37	61.7
	Grid	13	21.7
	Indifferent	10	16.7
Direct preference Task	Economic	17	23.0
	Environmental	43	58.1
	Social	14	18.9

*N = 60, only includes participants who chose identical tasks

4.2.3 Counting analyses of attribute levels

Tables 4 to 9 show the results of the counting analysis of the six attributes separately. Together with the rate an attribute level was chosen, the results of the chi-square tests are shown. The within attribute Chi-square value indicates whether levels of that attribute differ significantly in their frequency of choice. A small chi square means that observed data fits expected data well. The significance value indicates whether the Chi-square test decided whether effects are significant or not. Effects with $p < 0.01$ are more significant than those with $p < 0.05$.

There are significant differences in the amounts the different levels of the *CO_2 emissions* attribute were chosen. With 50%, the choice tasks containing the level "low" were chosen most often. Choice tasks that included the level "medium" were chosen 34% and ones with "high" only 14% of the time.

Table 4. Counting analysis *CO_2 emissions.*

Level	*Low*	*Medium*	*High*
Counts	0.523	0.337	0.138
Within Attr. Chi-Square		148.113	
Significance		$p < .01$	

Differences in the chosen amount of the three different *selling price* levels were significant as well. Alternatives with the highest selling price, i.e. 20 €ct/kWh, were

Table 5. Counting analysis *Selling price.*

Level	*10 €ct/kWh*	*15 €ct/kWh*	*20 €ct/kWh*
Counts	0.523	0.337	0.138
Within Attr. Chi-Square		148.113	
Significance		$p < .01$	

chosen most often with 40%. The low and medium price levels, i.e. 10 and 15 €ct/kWh, were both chosen about 30% of the times.

The differences in the choices of the attribute levels of the *social connection to electricity partners* was less, yet still significant. The option "none" was least preferred and was chosen 28% of the times. The other two attribute levels "direct" and "close" were both chosen around 35% of the times.

Table 6. Counts analysis Social connection.

Level	None	Direct	Close
Counts	0.284	0.350	0.366
Within Attr. Chi-Square		7.609	
Significance		$p < .05$	

Differences in choices of the levels of the attribute *additional effort* were again more significant. Participants preferred choosing alternatives which contained the attribute level "0 h/month" selecting 43% of the times. The level "4 h/month" on the other hand was least preferred and chosen in 22% of cases. The remaining 34%, alternatives with the medium level with "2 h/month" were chosen.

Table 7. Counting analysis Additional effort (time).

Level	0 h/month	2 h/month	4 h/month
Counts	0.434	0.344	0.223
Within Attr. Chi-Square		44.546	
Significance		$p < .01$	

The amounts alternatives with the different levels of the attribute *improved efficiency* were chosen differed significantly. Most respondents, i.e. 40%, chose alternatives with the highest efficiency improvement of "30%". The medium level of "15%" was chosen 34% of the times, and the low level of "0%" only in 27% of selected alternatives.

Table 8. Counting analysis *Improved efficiency.*

Level	*0%*	*15%*	*30%*
Counts	0.265	0.339	0.395
Within Attr. Chi-Square		16.988	
Significance		$p < .01$	

The differences in the chosen levels of *self-sufficiency* were again significant. Alternatives with the level "high" were picked the most with about 40%, whereas only 30% of times alternatives containing the level "low" were chosen. The medium level was picked in 30% of cases.

Table 9. Counting analysis *Self-sufficiency.*

Level	*Low*	*Medium*	*High*
Counts	0.292	0.316	0.392
Within Attr. Chi-Square		10.841	
Significance		$p < .01$	

Counting analyses can show joint effects as well. This would be for example how often certain levels of two attributes, e.g. CO_2 emissions and Selling price, were chosen together. Yet, the joint effects were not significant for any attribute combinations and are therefore not reported. Overall the differences in the amounts the levels per attribute were chosen, were significant. Again, it must be repeated that the counts analysis is only a preliminary measure for the preferences of attribute levels because some levels may appear more often than others, although the likelihood of appearance is the same. Therefore, the HB analysis was performed, and its results are presented in the next section.

4.2.4 HB: utilities and importance scores

Fit of the HB model.

The HB model computation was set to 100,000 iterations (of which the first 50,000 were discarded) before convergence was assumed. The values are based on a logit model that calculates the probabilities of respondents choosing tasks. The likelihood is the product of those probabilities over all respondents and tasks. Because this value gets very small, its logarithm is considered for the calculations (Orme, 2009). The Percent Certainty indicates where the analysis results lie within the range of complete chance and the perfect solution. A value of 0 would mean that the model fits the data only at chance level, while a value of 1 means that the data is a perfect fit of the model. The Percent Certainty calculated for this DCE was 0.723, which indicates that the log likelihood is on 72.3% between chance value and the perfect fit value (Orme, 2009). The Fit Statistic Root Likelihood (RLH) is the geometric root of likelihoods across all respondent tasks. It can be interpreted as follows: Respondents have 3 alternatives to choose from. At a random guess each alternatives probability of being picked is 1/3 (33%). Again, a value of 1 would indicate perfect fit of the model. The RHL in this model has a value of 0.738, and thereby the present model has a fit that is just over two times better than the chance model. The model is able to predict the outcome of a choice task correctly 73.8% of the time (Orme, 2009).

Average utility scores.

By using the Hierarchical Bayes estimation method, the part-worth utilities of the attribute levels were calculated. The part-worth utilities were zero-centred, i.e. normalised, in order to facilitate their interpretation. The higher the utility score of an attribute level is, the more attractive it has been on average for respondents in the study. A negative utility score does not imply that it the attribute level is unattractive, but solely that it is less attractive relative to other levels. An average utility score is built from the individual utility scores of each respondent and for each attribute level. The average utility scores cannot be compared across attributes but only across levels within the same attribute. A table with all zero-centred part-worth utilities and standard deviations is given in Appendix C: DCE results. Figures 6 to 11 give a graphic representation of the utility scores.

It becomes apparent that the HB analysis does not bring new insights compared to the counting analyses. All attribute levels appear in the same order of being preferred by respondents. As the HB estimation model is still a more elaborate method of analysis, one can now assume that these results are very likely to be solid. Within the attribute *CO_2 emissions,* the level low has the highest utility and is therefore preferred, and the level “high” has the lowest utility. For the attribute *selling price*, the highest price which was 20 €ct/kWh has the highest utility, and the lowest price which was 10 €ct/kWh has the lowest utility. Having the choice of the *social connection with electricity trading partner*, on average respondent prefer someone they know closely, e.g. friends or family, which was indicated by the level having a higher utility, than the other two level of the attribute. When it comes to the attribute *additional effort (time)*, no additional amount of time spent per month was preferred, while an additional 4 h/month had the lowest utility score. The *improved efficiency* level of 30% had superior utility score, compared to the ones of the levels 15% and 0%. Finally, the attribute *self-sufficiency* had the highest utility value for the level “high” and the level “low” the lowest utility.

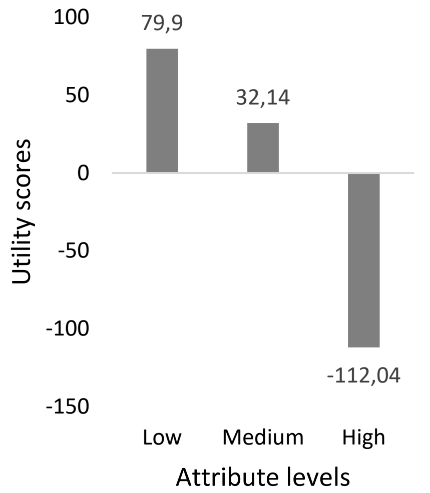

Figure 6. Zero-centred part-worth utilities of the attribute *CO_2 emissions.*

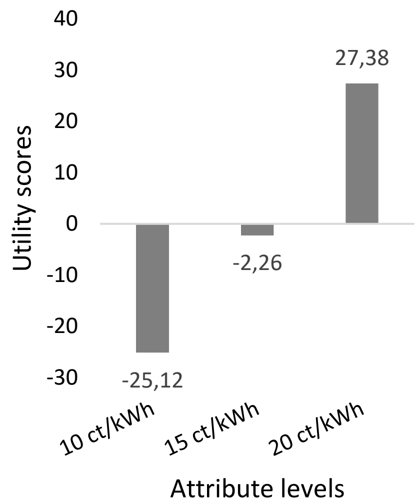

Figure 7. Zero-centred part-worth utilities of the attribute *Selling price.*

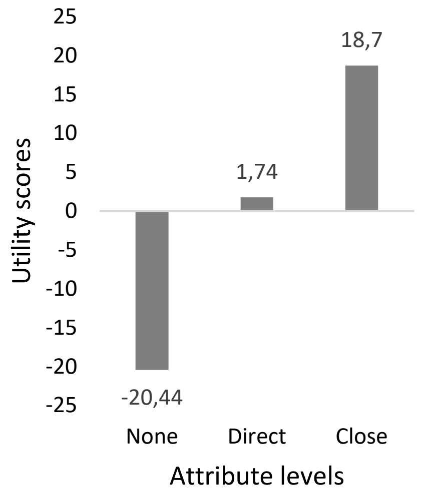

Figure 8. Zero-centred part-worth utilities of the attribute *Social connection.*

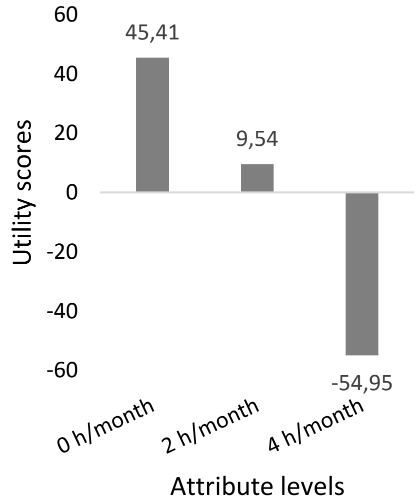

Figure 9. Zero-centred part-worth utilities of the attribute *Additional effort.*

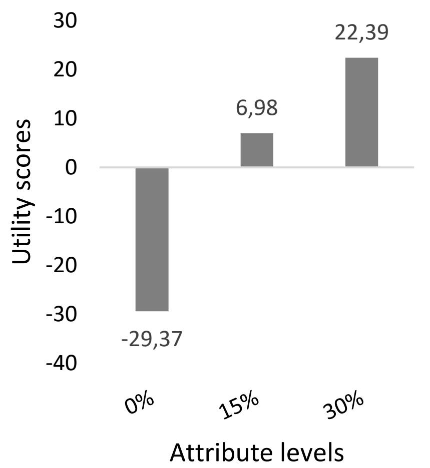

Figure 10. Zero-centred part-worth utilities of the *attribute Improved efficiency.*

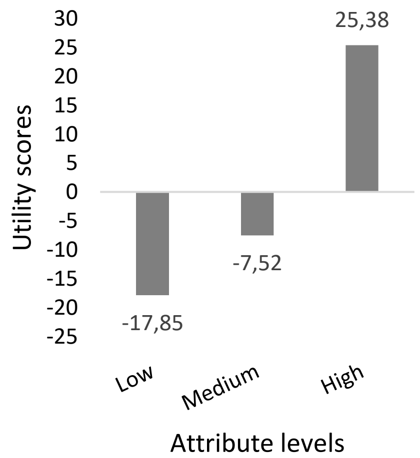

Figure 11. Zero-centred part-worth utilities of the attribute *Self-sufficiency.*

Average importance scores.

Apart from the part-worth utilities the HB model also estimates the attributes importance scores, which indicate the importance of an attribute relative to the other attributes. A table of the importance scores with standard deviations is given in Appendix C: DCE results, while Figure 12 gives a graphic representation.

With 37.74% the attribute *CO_2 emissions* had the highest impact on respondents' decision-making process by far. This is followed by the attribute *additional effort (time)* with 19.60%. After this the relative importance of the remaining four attributes *selling price, improved efficiency, self-sufficiency* and *social connection* is close together and appears in this order while ranging from 12.58% to 8.53%.

These results imply that the average respondent's choices are mostly influenced by the attribute CO_2 emissions, while the other five attributes infuence the decisions to a lesser extent.

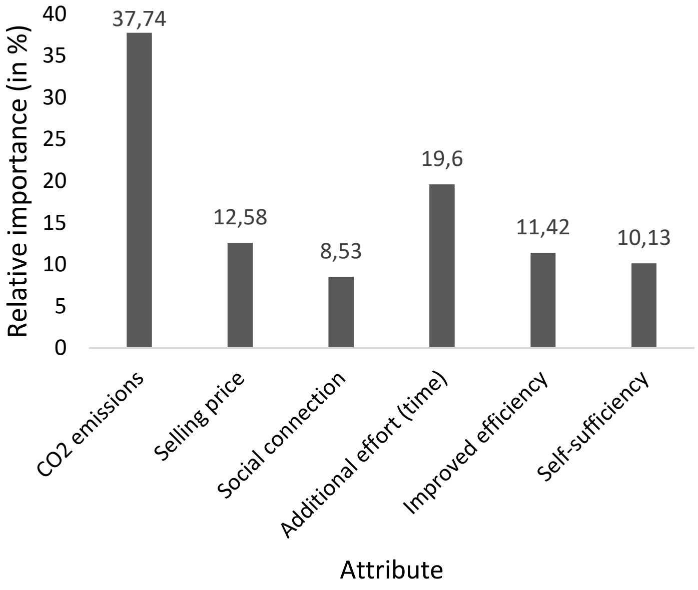

Figure 12. Average importance scores

The importance scores have to be interpreted with caution, because they are somewhat dependent on the range between attribute levels. If an attribute's levels are significantly different than it is likely that it will have a larger impact on respondents' decisions. The same goes for the order the attributes appear in. The attributes that appear first may have more influence on the respondents' decisions simply because they are the first ones they see (Logar, Brouwer, & Campbell, 2020).

4.2.5 Insights from the DCE analysis

In summary, it can be stated from the DCE analysis that on average, respondents' choice for an electricity trading concept is most influenced by the attribute *CO_2 emissions* and that withal a low level of CO_2 emissions is preferred over medium and higher level. The attribute that showed to have the second most influence on respondents' choices was *additional effort (time)* with the level 0 h/month being the preferred one on average. The remaining four attributes *selling price, improved efficiency, self-sufficiency* and *social connection* seem to be equally important for the decision-making process of respondents with the most desired levels being 20 €ct/kWh for the selling price, 30% of improved efficiency, high self-sufficiency, and a close social connection with the electricity trading partners.

It therefore seems like the average prosumer prefers an electricity trading concept that provides them with electricity from low CO_2 emitting sources, while the trading itself requires no additional effort in terms of time. Furthermore, the average prosumer would like to acquire the highest selling price for traded surplus electricity, that they prefer exchanging with someone they have a close social connection to. Finally, the electricity trading concept should provide them with a high level of self-sufficiency and improve the efficiency of electricity supply. To gain more insights, the next sections will deal with potential significant differences in trading preferences of prosumer subgroups, which were identified based on prosumers' characteristic and attitudes.

4.3 Identification of subgroups

4.3.1 Prosumer characteristics results

The first section of the survey asked participants questions about their renewable DER, their current energy supplier, their membership in energy cooperatives, and their willingness to give surplus electricity for free or for indirect financial compensation.

The participating prosumers were asked why they decided to install a renewable energy system. They were provided with five answers of which they could choose several. The percentages of agreement to the provided reasons by participants is given in Table 10. With over 85%, the vast majority stated they wanted to tackle the climate change problem by being part of the clean energy transition. Three quarters of the respondents wanted to reduce their energy costs. The reasons of having more control over energy production and use, there being a subsidy, and having an interest in the technology were each chosen by about a third of the participants. Additionally, the option was given to provide other reasons. Among these other reasons were economic reasonings ("interesting business case", "increasing the house's value") and increasing independence. A list of all other responses is provided in Appendix D: Prosumer characteristics - other responses.

Table 10. Reasons for installing renewable DER

What was/were the reason(s) you installed this renewable energy system?	% (of N=74)
Tackling the climate change problem by being part of the clean energy transition	86.49%
Having more control over my own energy production and use	32.43%
Reduce energy costs	74.32%
There was/is a subsidy	31.08%
Interest in the underlying technologies	37.84%

The next two questions regarded the surplus electricity that was generated with the prosumers' systems (see Table 11). 74% stated that they knew how much surplus electricity they had generated in the last year and provided an amount. The total average per respondent was 977 kWh per year. The respondents' answers were combined into groups. Just under 10% indicated that they had a negative electricity balance at the end of the year, i.e. they produced less than they consumed. Around 20% stated that they had no surplus electricity produced. With 45%, most prosumers generated a positive amount under 1000 kWh, and about 15% in between 1000 and 2500 kWh. Only very few respondents generated more than 2500 kWh of surplus.

Table 11. Surplus electricity generated with the renewable DER

		% (of N=74)
Are you aware about how much surplus electricity you generate with this system?	yes	74.32%
	no	25.68%
How much surplus electricity did you have at the end of last year?	in kWh	% (of N=55)
	-1000 to 0	9.09%
	0	21.82%
	0 to 1000	45.45%
	1001 to 2500	16.36%
	Over 2500	7.28%
Mean amount of surplus electricity	976.909	
Standard deviation	2481.064	

When asked about the reason(s) for choosing their current energy provider, the majority (72%) indicated they chose them because the supplier provided green energy, as Table 12 shows. For about one third of participants the company's reputation was a factor in their decision. Every fifth respondent made the decision based on the company offering the lowest costs. Receiving a bonus, the provided technology and recommendations played a minor or no role for most respondents. Over a third of the survey's participants gave an additional or other answer. The full list is given in Appendix D: Prosumer characteristics - other responses. Nine times the energy supplier was chosen because of or because it is an energy cooperative. Again, nine respondents gave another economic reason, for example that their supplier offered the best price for selling them surplus electricity. Two responses were related to having made good experiences with the provider, while two more do currently not have a provider. The remaining other responses were related to a unique feature the provider offered, for example the option to buy a share of a wind turbine.

Table 12. Reasons for choosing energy provider

Why did you choose your current energy provider?	% (of N=74)
Green energy supply	71.62%
Lowest cost	21.62%
The company's reputation	29.73%
Bonus for becoming a new customer	5.41%
Provided technology (e.g. an energy app)	1.35%
Recommendation by family or friends	0.00%

Of the surveyed prosumers, almost half (45%) were a member of an energy cooperative or community. The most prominent reason to become a member among them was to tackle the climate change problem (82%), and to decentralise the energy production in the Netherlands (65%). About half of the cooperative members wanted to create a sense of local community (50%) and to improve revenues for the community (41%). Only few chose the reasons of reduced energy costs, there being a subsidy, and to have access to renewable energy technologies. The reasons are summarised in Table 13. Again, there was the option to provide other reasons, which are provided in Appendix D: Prosumer characteristics - other responses.

Table 13. Energy cooperative membership

Are you a member of an energy cooperative or community?		% (of N=74)
	yes	45.95%
	no	54.05%
What was/were the reasons you became a member of an energy cooperative?		% (of N=34)
Tackling the climate change problem by being part of the clean energy transition		82.35%
Decentralise energy production		64.71%
Create a sense of local community		50.00%
To have access to renewable energy source technologies		14.71%
Reduce energy costs		8.82%
There is/was a subsidy		2.94%
Improve revenues of our collective or community		41.18%

The final two questions in this section regarded the willingness to exchange surplus electricity without a return or for an indirect financial return (see Table 14). While 40% of respondents would not be willing to give surplus electricity for free under any circumstances, this percentage was with 24% significantly lower for an indirect financial return. Of the participants who would give away surplus for free, 77% would give it to someone who can't afford electricity, 52% to a family member, 50% to a public facility, 39% to a friend, 30% to someone in their community they know, and 14% to someone they do not know. Of the participants who would give away surplus for an indirect monetary return, 72% would give it to a public facility, 70% would give it to someone who can't afford electricity, 50% to someone in their community they know, 43% to a family member, 41% to a friend, and 34% to someone they do not know.

Table 14. Willingness to give surplus electricity for free or for an indirect monetary return

Would you be willing to give surplus electricity…	*for free?*	*for an indirect monetary return?*
	% (of N=74)	% (of N=74)
No	40.54%	24.32%
Yes	59.46%	75.68%
If yes, to…?	% (of N=44)	% (of N=56)
Someone in your neighbourhood/community you don't know	13.64%	33.93%
Someone in your neighbourhood/community you know	29.55%	50.00%
A public facility in your community, i.e. school, swimming pool, youth centre	50.00%	71.43%
A household that can't afford electricity	77.27%	69.64%
A friend	38.64%	41.07%
A family member	52.27%	42.86%

4.3.2 Attitudes results

The three constructs environmental, community and technological attitudes were assessed with two statements each to be answered on a five-point Likert scale ranging from 1 (fully disagree) to 5 (fully agree). Table 15 gives the results of the responses to the statements in terms of means and standard deviations. The internal consistency of the two statements measuring one construct was assessed with the Cronbach's Alpha. With values over 0.6 for all three constructs are internally consistent, i.e. the two chosen statements are reliably measuring the same concept (Peterson, 1994).

The first statement measuring the construct *environmental attitude* received a high mean value of 4.5, indicating that the majority of respondents is concerned about humanity's impact on the climate and the environment. The second statement for the construct received a lower mean value of 3.78, indicating that the respondents on average are in between neutrality and agreement to paying attention to ecological criteria when buying products and services.

The two statements measuring the construct *community attitude* were assessed with lower agreement values. The mean value for feeling a strong identification with the local community was 3.46, and the mean for thinking of many community members as friends with 2.99.

The last two statements which measured the construct *technological attitude* were both rated with higher agreement. Respondents' mean value for the statement about learning new technologies being easy was 4.11 and the mean for enjoying to explore new technologies was 4.27.

Table 15. Cronbach's alphas, means and standard deviations (SD) of statements, N = 74

Construct	*Cronbach's alpha*	*Statement*	*Mean*	*SD*
Environmental attitude	0.6472	I am concerned about human behaviour and its impact on the climate and the environment.	4.50	0.095
		I always pay attention to ecological criteria when buying products and services.	3.78	0.113
Community attitude	0.8180	I feel a strong identification with my local community.	3.46	0.089
		There are many people in my local community whom I think of as friends.	2.99	0.108
Technological attitude	0.8323	Learning how to use a technological device is easy for me.	4.11	0.087
		I enjoy exploring new technologies.	4.27	0.089

4.3.3 Socio-economic characteristics of the sample

In the last section of the survey, participants were asked to provide some information about their socio-demographic background. A table with an overview is presented in Appendix E: Socio-economic characteristics of sample. The majority of respondents were aged between 56 and 65 (38%) and between 46 and 55 (28%). The age groups 36 to 45 and older than 65 were represented to a lesser extent with 16% and 14% respectively. Only 4% of respondents were younger than 35, and none younger than 25. Of the entire sample 85% were males, and only 12% females. One participant indicated they identify as third gender/non-binary. The greater part of the respondents holds a master's degree (36%), 9% hold a PhD, 8% a university bachelor's degree, and 28% a degree from a university of applied sciences. 13% pursued vocational training, and 3% hold a high school diploma. Most participants live in either a medium-sized city (35%) or in a rural community (31%), while 22% live in large cities and 12% in small towns. With 45%, the largest share of participants lives in a household with a total of two persons, while 19% live in a household of three, 23% of 4 and 8% of five or more. Five percent live on their own. Most surveyed households have a yearly net income that lies between €40,000 and €59,999 (35%). Five% have an income under €20,000 and 15% have between €20,000 and €39,000. 20% of participants stated their household's net income was between €60,000 and €79,999 and 24% had over €80,000. In summary, the sample can be described as being dominated by middle-aged males with a high level of education living in smaller sized households within medium-sized cities or in rural areas, who have a relatively high household net income compared to the Dutch average of €31,000.

4.4 Subgroup analyses of the DCE

Based on the results presented the previous section, several subgroups were identified. The DCE analyses were repeated separately for these subgroups in order to identify differences. This allows to give recommendations how P2P trading platforms can be marketed specifically to different prosumer groups. It has to be noted that some of the sample sizes of the analysed subgroups are very small. This has an impact on the statistical significance and representativeness of the results, which therefore have to be interpreted with caution. Nevertheless, they can give an indication of the diverseness of prosumer subgroup's preferences.

The following subgroups had significant differences in the results of the DCE. The sample size of each subgroup is indicated in brackets.

1. Energy cooperative member (N = 34) vs. no member (N = 40)
2. Willing to give surplus electricity for free (N = 44) vs. not willing (N = 30)
3. Willing to give surplus electricity for an indirect monetary (N=56) vs. not willing (N=18)
4. Environmental attitude smaller than or equal to 3 (N = 13) vs. larger than 3 (N = 61)
5. Technological attitude smaller than or equal to 3 (N = 5) vs. larger than 3 (N = 69)
6. Age under 46 years (N = 15) vs. 46 years and older (N = 59)
7. Net household income under €60,000 (N = 41) vs. €60,000 and higher (N = 33)

All tables with the contrasting juxtaposition of the subgroups' average part-worth utilities and average importance scores that were significantly different can be found in Appendix F: Subgroup analyses of DCE. In the following, only the significant differences between subgroups are reported. Significance was tested using a two-sided t-test to compare the means of utilities and importance scores.

Energy cooperative membership.
The sample was divided into two groups, one consisting of energy cooperative members and one of non-members. The average utility scores for the attribute levels 10 €ct/kWh and 20 €ct/kWh within the attribute *selling price* differed significantly between members and non-members. Energy cooperative members' average utility was significantly higher for the lower price and significantly lower for the higher price. This result indicates that members on average have less extreme preferences for the amount of money they can sell their surplus electricity for. This is also indicated by a significantly lower importance score for the attribute *selling price*, meaning that the attribute has a lower impact on energy cooperative members' decision-making process, compared to non-members.

Willingness to give surplus electricity for free.
For the next two subgroups, the sample was divided based on the choice whether they would give surplus electricity for free to any of the offered option, or not. They were significant difference in the average utilities of the low and the high level of the *CO_2 emissions* attribute. Participants who would give free surplus had a significantly higher utility value for low CO_2 emissions and also a significantly lower utility for high CO_2 emissions than the contrasting subgroup. The importance score of this subgroup for the attribute *CO_2 emissions* was also significantly higher. Next, there were significant differences in the utilities for the low selling price level (10 €ct/kWh) which had a higher utility for the subgroup that would provide free surplus. The average importance score for the attribute *selling price* was significantly higher in the group of respondents who would not prove free surplus. The next significant differences were found in the two levels "direct" and "close" for the attribute *social connection with electricity trading partner*. The level "close" had a significantly higher utility for the group that was willing to give free surplus, and the level "direct" had a higher utility in the other group. Finally, the level "4 h/month" within the attribute *additional effort* had a higher utility for the group that would give surplus for free.

Willingness to give surplus electricity for indirect monetary returns.

The two subgroups identified through their willingness to exchange surplus electricity for indirect monetary returns also showed significant differences in utilities. The utility of the level “medium” in *CO_2 emissions* was significantly lower for those who would accept such indirect returns. The level “0 h/month” of the attribute *additional effort* had a significantly higher utility for those that would not accept a return of this kind. The intermediate level “2 h/month” on the other hand had a significantly lower utility for them. Another significant difference was found in the “high” level for *self-sufficiency*, which had a significantly higher utility value for those who wouldn’t accept an indirect return.

Environmental attitude.

The sample was divided based on their attitude towards the environment. One subgroup consisted of those who ranged from disagreement to neutrality to the presented statements, and the other subgroup of those who agreed to the statement. For the attribute *CO_2 emissions,* the environmentally conscious subgroups had significantly higher utility values for low emissions, significantly lower utilities for high emissions, and a significantly higher importance score than the more unconscious group. Furthermore, the environmental conscious group had higher utility values for a lower and medium selling price (10 €ct/kWh and 15 €ct/kWh) and lower values for the high selling price (20 €ct/kWh). They also had a significantly lower importance score for the attribute *selling price*. There was also a significant difference in the attribute level “medium” of *self-sufficiency*, which was higher for the environmentally conscious group.

Technological attitude.

Next, the sample was split up in a technologically interested group (technological attitude > 3) and a less interested group (technological attitude ≤ 3). The technologically interested subgroup had a significantly higher utility value for” low” *CO_2 emissions*, while the less interested subgroup had a significantly higher utility for the level “0 h/month” of the attribute *additional effort.*

Age.

Based on the indicated age, the sample was divided into younger (age < 46) and older (age ≥ 46) respondents. Younger participants had significantly lower utilities for the low *efficiency improvement* level of “0%” and significantly higher utilities for the intermediate level of “15%”. They also had a higher average utility value for the level “low” in *self-sufficiency* and placed significantly less importance on this attribute.

Net household income.

The two final identified subgroups that showed significant differences were divided based on their household’s yearly net income. Respondents that indicated their household had more than €60,000 at their disposal, had a significantly lower utility for the intermediate selling price (15 €ct/kWh). Yet here it should be noted that they also had a lower utility for the higher selling price and a higher utility for the lower selling price than households with less than €60,000 net income, although this difference was small and therefore not significant.

5 Discussion

In this chapter, the results of the survey are discussed in three ways. In Section 5.1 Theoretical implications, the results are interpreted regarding their theoretical implications. The results are compared to findings from previous literature in order to identify potential similarities, contradictions and extensions. In Section 5.2 Practical implications, several practical implications regarding the marketing and design of P2P electricity trading platforms are presented, which are supported by this study's findings. Finally, the limitations of this research and subsequent recommendations for future research are particularised in Section 5.3 Limitations.

5.1 Theoretical implications

The results analysis revealed that to a significant extent, the degree to which the electricity trading system is related to CO_2 emissions had the highest impact on the choice behaviour of the surveyed prosumers. This implies that Dutch prosumers would make trade-offs, for example accept a lower selling price, to ensure that their electricity use is associated with low CO_2 emissions. This is in line with previous findings that showed that a positive attitude towards the environment is the main predictor for the willingness to participate in P2P electricity trading (Hackbarth & Löbbe, 2020; Reuter & Loock, 2017; Wilkinson et al., 2020), and contradicts studies that identified economic attributes to be most influential for households' trading behaviour (Hahnel et al., 2020; Mengelkamp et al., 2019). It must be noted that these previous studies were conducted with individuals located outside the Netherlands, which may explain this contradiction. In the context of this survey, the dominance of the environmental attribute may be explained with a large share of respondents who were identified as being environmentally conscious. For instance, when asked for the reason that the renewable DER was installed, the majority of prosumers wanted to be part of the clean energy transition, which suggest that the reduction of CO_2 emissions was a main motivator for becoming a prosumer in the first place.

The second priority of prosumers when choosing an electricity trading concept, was the amount of additional effort (in terms of time spent on a monthly basis) that would be potentially required for managing the trading processes. Prosumers were more reluctant to choose trading scenarios that included either two or four hours per month of additional effort. This was particularly the case for prosumers which were identified to have lower interest in new technologies and stated they had difficulties when using them. This finding supports similar tendencies which were found in other studies where an increasing need for coordination was identified as a potential risk for the adoption of P2P electricity trading (Reuter & Loock, 2017) and where systems with easy implementation and comfortable service bundles were preferred (Hackbarth & Löbbe, 2020). This implies that a well-managed and highly automated trading platform is vital for the success of P2P trading.

The price for which surplus electricity can be sold on the other hand, played a significantly lower role in the decision-making of prosumers compared to the two previously mentioned attributes. Still when choosing a trading scenario, prosumers preferred higher selling prices over lower ones, which is in line with findings from other studies (Hahnel et al., 2020; Mengelkamp et al., 2019). This also corresponds to a majority of respondents having stated that they installed the renewable DER in order to reduce their energy costs. This finding suggests that while the economic benefits of P2P trading should be emphasised, they may not play the most significant role in prosumers decision to participate in P2P trading. An explanation could be that prosumers in the Netherlands are currently receiving high economic benefits under the existing net metering scheme, and that many are not aware of the planned replacement with a less economically attractive FiT system in the near future. Especially, members of energy cooperatives attached very little importance to the selling price of surplus electricity. This is an indication that energy cooperative members attach greater importance to the non-economic aspects of energy trading. With the emergence of more energy cooperatives and increasing number of members in the past few years in the Netherlands (HIER opgewekt & RVO, 2019), their potential role as facilitator and early adopters of P2P electricity trading systems should be investigated in more detail.

The next finding concerns the extent to which prosumers found it important that their choice of electricity trading influences the overall efficiency of electricity supply. While preferring systems with the highest possible efficiency improvement, prosumers' choices were not heavily influenced by this attribute. The role of efficiency improvements for individuals' decisions has not been investigated before in the context of P2P electricity trading. Yet, it is one of the benefits over large-scale centralised electricity grids (Jogunola et al., 2017). Therefore, the communication of this aspect may be beneficial to achieve increasing participation, despite the fact that it was not seen as one of the most important aspects. Especially so, because the improved efficiency has positive impacts on both the CO_2 emissions and the selling price by utilizing more electricity from the prosumers' renewable DER. Prior to this, the precise effects of P2P electricity trading on improved grid and DER efficiency should be thoroughly investigated in future research project, for example by extensively monitoring real-world trials.

Although trading scenarios with high levels of self-sufficiency were preferred by prosumers, their decisions were not highly influence by the degree of self-sufficiency presented. This corresponds to the additional finding that only a minority of prosumers installed their renewable DER to have more control over their own energy production and use. In addition, this matches statements given in the interviews with prosumers that preceded the survey, in which many interviewees mentioned that they expect to remain reliant on large centralised grids and thereby big energy providers. Still, some interviewees expressed that self-sufficiency is an aspect that they deem important in the light of insecurities of future electricity supply related to the phase-out of electricity from fossil sources in the Netherlands. This dichotomous finding both supports and contradicts literature that ascertained that increased autarky, which is related to the concept of self-sufficiency, negatively influences individuals' willingness to participate in P2P electricity trading (Ecker et al., 2018). Despite the fact, that self-sufficiency does not seem to be as important to prosumers as other aspects of electricity trading, the concept should be investigated again when prosumers are confronted with potential future insecurities of electricity supply and remuneration schemes.

The ability to choose electricity trading partners according to one's preferences is a unique feature of P2P electricity trading. The preferences of Dutch prosumers for the social connections to electricity trading partners have not been investigated in previous research. Although having the smallest impact on the choices made by the participating prosumers, a valuable finding was that prosumers preferred having a trading partner they stand in a close social relationship with, i.e. a family member or friend. This contradicts findings by Reuter and Loock (2017), who found no indication for preferred relations to trading partners. In this research, the tendency to prefer socially close partners was significantly higher for prosumers who stated that they would be willing to provide surplus electricity for free. The willingness to provide free surplus electricity to certain groups was observed in a majority of investigated prosumer. Even a larger share was open to accept non-monetary indirect forms of compensation for giving electricity to other households and facilities. Many prosumers are willing to make such an exchange with households that cannot afford electricity themselves. This supports the idea that prosumers see electricity as social capital that they give away to consumers in need (Jogunola et al., 2017), and the previous finding that participants of P2P electricity platforms show a high interest in social equity (Wilkinson et al. 2020). Furthermore, these kinds of exchange are likely to happen with institutions within the community of prosumers, which emphasises the community aspects of P2P electricity trading. Next to these groups, non-monetary compensation is more likely to be accepted with family members, friends and familiar community members. This corresponds with findings in the work of Singh et al. (2018) about P2P returns in off-grid energy communities in rural India. Although these were specific to the investigated area, Singh et al. (2018) indicated that they may also be valid for smart decentralised grids located in the global north. Hence, this research partially confirmed this presumption for prosumers in the Netherlands.

5.2 Practical implications

Next to the theoretical implications of this research, the findings support various practical implications that concern to whom and in what way P2P electricity trading can be marketed, the design of a trading platform, the potential role of energy cooperatives, and finally the regulatory policies surrounding P2P electricity trading.

A vital part of the success of P2P electricity trading is determined by the efforts made to market the idea, especially to prosumers who are unaware of the concept. The findings from this research shed light on the aspects that prosumers find most important when trading surplus electricity and can therefore be used to give recommendations about the messages that should be communicated when marketing a P2P electricity trading platform. Accordingly, in its core the message should emphasise on the environmental benefits of P2P electricity trading over the status quo, which in most cases is the feeding into the central electricity grid that is currently dominated by non-renewable energy source with higher CO_2 emissions. This can be achieved by making prosumers aware of the opportunity to utilise more of their surplus electricity locally and to reduce energy losses during grid transmission, leading to a reduction of less sustainable electricity imports from the central grid. As the vast majority of prosumers stated that they wanted to be part of a clean energy transition by installing renewable DER, this message can also be used to attract them into P2P electricity markets as forerunners of an innovative concept that advances the clean energy transition. Next to this, the expected changes in the compensation schemes for feeding-in surplus electricity into the grid should be brought to prosumers' attention. With the abolishment of the net metering scheme envisaged by the government of the Netherlands, the economic benefits of renewable DER for households will change for the worse. Raising this issue while explaining how P2P electricity trading can ultimately result in higher selling prices than conventionally feeding electricity into a central grid, has the potential to spark prosumers' interest in P2P electricity trading. Additionally, the transfer of knowledge about P2P electricity trading and the communication of the associated beneficial attributes can help closing the attitude-behaviour gap that is expected influence prosumers adoption of a novel trading system (Terlau & Hirsch, 2015).

The novelty and innovativeness of a P2P electricity market makes it a niche product or service for the foreseeable future (Hackbarth & Löbbe, 2020). Niche products and services usually offer at least one unique characteristic, which sets them apart from the mass market products and which motivates niche market customers to purchase them – sometimes even with a surcharge (Varadarajan & Jayachandran, 1999). To engage consumers in niche markets, providers should work closely with customers to define individual solutions, and it is important that trust is established (Toften &

Hammervoll, 2013). Communicating the unique characteristics of P2P trading can attract these niche market customers. The most outstanding unique trait is the possibility to exchange electricity with selected peers. Incorporating this information into marketing efforts can draw the attention of prosumers that attach high value to community aspects and social exchange to participate in P2P electricity trading.

The presented study only surveyed prosumers, yet even within this group, there were variations in responses which indicated that it is sensible to approach different prosumer groups in different ways. For instance, energy cooperative members attach less importance to high selling prices which can be addressed by putting more emphasis on the non-economic benefits when approaching this group with P2P electricity trading. Ideally, a P2P electricity trading platform manages to reach every prosumer with their specific preferences This can be achieved by having a platform design that satisfies different preferences accordingly. However, the finding that prosumers found it important to have minimal additional effort when trading surplus electricity makes it clear that a trading platform should ensure that trades can be carried out without substantial additional effort. The B-DER project strives to achieve this effortlessness by incorporating an intelligent agent system that enables automatic electricity transactions between peers. Additionally, as reaction to the finding that a majority of prosumers are open to the idea to provide surplus for free or non-monetary compensations, the design of the trading platform should include different compensation schemes to choose from. Together with this the platform should provide the option to freely choose electricity trading partners according to prosumers' personal preferences. In response to most survey participants describing themselves as has having an affinity for technological innovations, a P2P trading platform should offer the possibility to prosumers to be more engaged in the platform, for example by also offering an option to perform non-automated electricity trades.

In the preceding interviews with prosumers, several interview partners mentioned that they consider P2P electricity trading as an interesting concept for energy cooperative in particular. This supports the proposed idea that energy cooperatives can act as forerunners and facilitators for P2P electricity trading. As a result, energy cooperatives can be included into the process of setting-up P2P trading or they can be utilised as initializing and governing institution of the P2P electricity market (Reuter & Loock, 2017). Cooperatives can also use their network of members to foster peer effects. Although peer effects were not investigated directly in this research, the finding that prosumers prefer closer connections to electricity trading partners hints towards the concept of using peer effects to make P2P trading known to more people. These peer effects can emerge in form of word of mouth within communities through personal contact or in online communities. This is especially important because a P2P trading system work better when more peers are available, as supply and demand can be distributed between more trading partners. To utilise peer effects this information should be passed on to prosumers to incentivise them to promote P2P trading among members of their community. It has been observed that interactions in local communities had been sparked by recent developments around the world that have tied neighbours closer together (Alberti, 2020). For the past four months many people around the world, including the Netherlands, had to stay at home to prevent the spread of COVID-19 – a novel virus that has emerged in December 2019 and rapidly spread since then. This has potential to further nurture the idea of collaborative production, consumption and exchange within local communities – also in the field of renewable electricity production and consumption.

Finally, a set of clear policies and guidelines for P2P electricity trading in the Netherlands is required. For now, there are still many insecurities regarding the regulatory framework for P2P electricity trading, for example regarding the taxation of any potential profit made from selling surplus electricity. It can be expected that similarly to an increasing adoption of PV when individuals are aware of the costs and subsidies related to installing PV (Vasseur & Kemp, 2015), a good knowledge of cost and subsidies around P2P trading has positive impact on its adoption. Hence, the Dutch government should provide prosumers with these policies particularly in regard to prosumers' important role in reaching the targets the Netherlands agreed to meet in the Paris Agreement (United Nations, 2016).

5.3 Limitations

Several limitations of the research and their impact on the results were identified. First and foremost, a major limitation is the survey's rather small sample size of 74 respondents. With more than 400,000 prosumers in the Netherlands, an appropriate sample size should include at least 384 participants for the general questions (Krejcie & Morgan, 1970) and at least 56, but more ideal 112, for the DCE (Orme, 2019). Reasons for the small number of participants are the limited timeframe in which the study had to be completed, the decision to only include prosumers and the used distribution channels. Nevertheless, significance tests showed that enough datasets were available to receive reliable DCE results, which comes from the fact that each participant answered nine choice tasks, resulting in a total of 666 datasets. Still, a potential consequence of the small sample size is a reduced generalizability of the study from the rather homogenous socio-economic characteristics of the respondents. Hence, it cannot be ruled out that the study's findings are not applicable to the general population of Dutch prosumers. Reduced generalizability may also be a result of the fielding strategy for the survey. The used distribution channels can be related to the observed homogeneity regarding the socio-economic characteristics of the respondents. Additionally, potential participants with no access to the internet (or social media) are excluded from the study which was only available online. Also, results may be biased as several energy cooperatives were used to reach out to prosumers. As a consequence, 45% of respondents were members of energy cooperatives, although this percentage is much smaller in reality. Finally, it cannot be ruled out that the sample size and the respondents themselves were impacted by the extraordinary circumstances caused by the COVID-19 pandemic. To overcome this limitation, I propose that the survey could be repeated using several channels and over an extended period of time in order to increase the sample size and receive a more heterogenous sample that is representative of Dutch prosumers.

Furthermore, the selection process of attributes and attribute levels for the DCE is prone to be influenced by issues related to subjectivity. Although the final selection was made after reviewing relevant literature and interviewing experts and prosumers, subjectivity cannot be eliminated completely, thereby compromising the objectivity of results. The same applies to the selected attribute levels. If the levels differ quite significantly, it is more likely that the attribute has more influence on respondents' decisions. This could have been the case with the attribute *CO_2 emissions*, that received a significantly higher importance score than the other attributes. A similar effect may occur due to the ordering of attributes within the choice tasks. The attribute the is placed on top, in this case *CO_2 emissions*, may receive more attention than the lower attributes (Logar et al., 2020). Nevertheless, attribute ordering should not be randomised across choice sets as this would increase the complexity of the DCE. The rather complex nature of the DCEs potentially influences the choice consistency if participants are overwhelmed by the amount of information. This can cause problems regarding the validity of the results. The same goes for the length of the DCE, which although it was kept to minimum, may still have caused a sense of boredom among participants. This effect can be enhanced by the repetitiveness of choice tasks. To overcome this, the survey was pre-tested with several individuals, and the results from the validity analysis (see Section 4.2.2 Analysis of holdout tasks for validity and first indications) reveal that respondents generally paid attention when filling out the survey. Yet the decision to keep the survey to a minimum length, resulted in shortcomings for other parts of the survey. Especially, for the survey section that assessed the environmental, community, technological attitudes, where each construct was measured using only two statements, which can be related to limitations in the reliability of the results (Eisinga et al., 2013).

Finally, the previously introduced intention-behaviour gap can cause issues regarding the applicability of results, because prosumers' stated preferences cannot directly be translated into their actual behaviour (Sheeran & Orbell, 1999). Therefore, recommendations have been made carefully by keeping in mind that real-life decision can differ from this study's results.

6 Conclusion

In this master thesis, a survey which included a DCE was conducted with prosumers in the Netherlands to elicit their preferences regarding P2P electricity trading. The final sample was predominated by middle-aged males with a high income and a high level of education. The main finding regarding the entire sample were that the environmental attribute *CO_2 emissions* was with 38% by far the most important factor influencing respondents' decisions about electricity trading concepts. The second most influential attribute was *additional effort (time)* with 20%, while the economic attribute *selling price*, which was expected to play a major role in the decision making, only came third with 13% and almost on the same level as the remaining three attributes *improved efficiency* (11%), *self-sufficiency* (10%) and *social connection* (9%). This shows that the decision about partaking in electricity trading among the participating prosumers is not solely financially driven, but highly influenced by the environmental impact of the consumed electricity and by the amount of extra time required. Furthermore, prosumers on average prefer a trading concept in which CO_2 emissions are low, while additional effort is minimal and selling prices are high. They also prefer the system to result in high efficiency improvements, high levels of self-sufficiency and to have close connections to electricity trading partners.

Based on their responses to the questions regarding their prosumer characteristics, their environmental, community and technological attitude, and their socio-demographic attributes, the sample was divided into several subgroups. The DCE analyses were repeated for these subgroups and their results compared in order to investigate how these differences influence preferences in P2P trading. First, the sample was divided into EC members and non-members. EC members attached less importance to the attribute *selling price* and were more likely to choose trading scenarios with lower selling prices. Secondly, many significant differences were found between prosumers who would provide free surplus electricity. They had higher importance scores for *CO_2 emissions* and lower ones for the *selling price.* Furthermore, having a close *social connection with electricity trading partner* had higher utilities in this subgroup. Third, the subgroup of prosumers with a higher environmental attitude had higher utilities for low CO_2 emissions and for low and medium selling prices. They also attached more importance to the attribute CO_2 emissions and less to selling price. Fourth, the subgroup with a higher technological attitude had higher utilities for low CO_2 emissions and lower utilities for zero additional effort needed. Fifth, the subgroup of older participants attached more importance to *self-sufficiency* and had lower utilities for the low self-sufficiency level. On the contrary, the younger subgroup had significantly lower utilities for zero efficiency improvements. Furthermore, the research conducted in this thesis strived to extend the current state of research on P2P electricity trading by investigating prosumers' willingness to provide surplus electricity for free or indirect financial returns. More than half of the respondents indicated that they would provide free electricity to certain groups, and three quarters would accept an indirect return. The entities they would most likely give electricity to under these conditions are households that cannot afford energy or public facilities in their community.

A P2P electricity trading scheme incorporates many elements that are considered important and are valued by prosumers in the Netherlands. This finding – together with the future policy changes in the Dutch net-metering system and an increasing employment of renewable DER by households – supports the concept of P2P electricity trading as a new way of empowering prosumers and driving the renewable energy transition in the Netherlands.

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Appendices

Appendix A: Interviews

A.1 Interview guide for prosumers

1. Can you please describe your energy generating system?
2. What were the deciding factors for you personally to install your energy system?
3. What is the status quo of the use of your surplus energy (, if you have any)?
4. If it was completely up to you: What would you like to do with the surplus energy of your system?
5. Have you heard of P2P energy trading or exchange?

If not, explain P2P energy trading:
Peer to peer or peer to community energy trading means that instead of feeding the surplus energy into the large energy grid back to an energy provider, you as prosumer can directly exchange your energy to – for example – a neighbour.
Ask if interviewee has any more questions regarding this.

6. What is the first thing – positive or negative – that comes to your mind regarding this?
7. Anymore advantages or disadvantages you associate with something like this?
8. Are there circumstances under which you would be willing to exchange surplus energy without getting a direct compensation in form of money?
9. Optional: Give these attributes and let interviewee reflect on them.
    - Self-sufficiency
    - Reliability of energy supply
    - Efficiency of electricity production
    - Data privacy
    - Additional effort (time)
    - Regionality of electricity production
    - Social connection with and location of electricity trading partners

A.2 Key take-aways from the interviews

Table A.2. Overview of the key point made by interviewees.

#	Length	Interviewee	Key take-aways
1	27:01 min Skype	- Prosumer - RE researcher - Coordinator at energy cooperative	Interviewee thought that P2P electricity trading was an interesting for energy cooperatives. They mentioned that there are differences in general prosumers and ones who are members of energy cooperatives. Main personal reason to install a renewable DER was the reduction of CO_2 emissions. They said that a financial benefit is most important factor when making a decision regarding the use of surplus electricity. They stated that becoming autonomous from the grid is not an issue in countries like the Netherlands, which have a reliable energy supply. They thought that the social factor in P2P electricity trading is an added value.
2	29:17 min Skype	- Freelance community energy advisor	The interviewee thought the most added value of P2P electricity would be for a local community. They would consider using P2P electricity trading in local and regional energy systems. They considered both the economic and community aspects most important.
3	26:53 min Skype	- Prosumer - Active member in energy cooperative - Consultant environmental economics	The interviewee's own motivation to install a DER were for financial, technology and environmental reasons. They stated that P2P electricity trading needed to have financial benefits in order to be widely accepted. They mentioned that P2P electricity trading needed to be easy to handle and without requiring any added time. They saw no added value in social aspects of P2P electricity trading. They put a strong emphasis on importance economic aspect in any kind of electricity trading.
4	28:00 min Skype	- Prosumer - Member energy cooperative	The interviewee's own motivation to install a DER were the investment subsidy and required roof renovations. They stated they would be willing to provide surplus electricity for free, for example to the local school. They thought that P2P electricity trading could be an interesting concept for energy cooperatives. They stated they liked the idea of energy self-sufficiency of local communities. They recognised that alternative solutions are needed when the net-metering stops. They mentioned that big energy providers slow down the energy transition in the Netherlands.
5	26:46 min Skype	- Prosumer	The interviewee's own motivation to install a DER were financial and sustainability aspects.

			They saw P2P electricity trading as an interesting option when the net-metering schemes ends. They mentioned that P2P electricity trading may have advantages over battery storage. They would only consider P2P electricity trading if no extra money and time were required to participate. The attached more importance to economic advantages than the option to choose trading partners with social connections. They could still imagine giving surplus electricity to friends or low-income households for free. For them self-sufficiency was not an important factor.
6	35:16 min In-person	- Project partner at RE consultancy	The explained the idea to realise a project about P2P electricity trading came from the idea to make communities self-sufficient and resilient. The stated that P2P electricity trading solves the problem of the ending of the net-metering system. They saw no strong potential for added benefits from choosing trading partners according to social connections. They believed that getting the highest price is the strongest motivator for most prosumers. They mentioned that including a gamification aspect into a trading platform is likely to get boring after a short time. They emphasised that no additional effort should be required to participate if platform is designed as planned. For them the biggest disadvantage was regulatory political side.
7	34:54 min Skype	- Founder of a European federation of citizen energy cooperatives - Founding member of energy cooperative - Prosumer	The interviewee thought that P2P electricity trading has potential for energy cooperatives. They stated they made good experiences with gamification aspects within energy platforms that track self-production and -consumption. They mentioned that 50% of members in their cooperative are interested in going off-grid and being completely autonomous in energy consumption with their community. They thought that an easy handling of electricity trades is an important aspect. The said that an financial advantage would be an additional incentive for prosumers to participate.
8	31:44 min Skype	- Academic expert for P2P electricity trading and choice experiments	*This interview regarded the methodology. The interviewee gave valuable tips for conducting DCEs and stated that the method was sensible for eliciting preferences in P2P electricity trading.*
9	35:40 min Skype	- Academic expert for energy cooperatives	*This interview regarded the finalisation of the survey. The interviewee gave final comments and recommendations regarding the questionnaire.*

Appendix B: Full questionnaire

Dear participant,

thank you for your interest in taking part in this survey. The survey is part of a master thesis project at Utrecht University, in which I want to investigate the preferences of electricity generating households for exchanging their surplus electricity within their local community. You are welcome to participate if you have any kind of renewable electricity generating system, e.g. photovoltaic panels, installed at your home or at another building that belongs to you.*

Any data obtained through this survey will be used for the master thesis research and policy recommendations purposes only. The data will be kept secure and confidential and will not be used by third parties or for any sort of commercial activity.

The questionnaire will take about 15 minutes to complete. We advise you to complete the survey on a computer or a tablet for maximum screen size. This survey uses cookies which save your progress and allow you to return to the survey at a later instance.

By completing this survey, you are an important part in the finalization of my master thesis and its resulting recommendations that can lead to support a successful energy transition in the Netherlands.

I appreciate your help and want to thank you for your participation. Please do not hesitate to contact me for any questions and suggestions.

Best regards,
Elena Georgarakis
e.z.georgarakis@students.uu.nl

**My master thesis is part of the B-DER project of the Copernicus Instituut at Utrecht University. The project aims to develop a platform on which people can exchange their sustainably generated surplus energy with the neighborhood and which guarantees a reliable decentralized energy grid.*

Next

First, I would like you to answer a few general questions about your renewable energy system.

Do you have a renewable energy generating system installed at your home*, such as photovoltaic panels?

- Yes
- No

*or another building that belongs to you

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0% 100%

What was/were the reason(s) you installed that renewable energy system?
(multiple answers possible)

- ☐ Tackling the climate change problem by being part of the clean energy transition
- ☐ There was/is a subsidy
- ☐ Having more control over my own energy production and use
- ☐ Interest in the underlying technologies
- ☐ Reduce energy costs
- ☐ Other: ______

Are you aware about how much surplus energy you generate with this system?

- ◯ Yes
- ◯ No

How much surplus energy did you have at the end of last year?

- ◯ in kWh: ______
- ◯ I don't know

Why did you choose your current energy provider?
(multiple answers possible)

- ☐ Lowest cost
- ☐ Bonus for becoming a new customer
- ☐ Provided technology (e.g. an energy app)
- ☐ The company's reputation
- ☐ Recommendation by family or friends
- ☐ Green energy supply
- ☐ Other: ______

Are you a member of an energy cooperative or community?

- ◯ Yes
- ◯ No

Definition: Energy cooperatives or communities represent an organised form of local communities that promote production and consumption of renewable energies.

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Why did you become a member of an energy cooperative or community?
(multiple answers possible)

- ☐ Create a local sense of community
- ☐ To have access to renewable energy source technologies
- ☐ Improve revenues of our collective or community
- ☐ Tackling the climate change problem by being part of the clean energy transition
- ☐ There is/was a subsidy
- ☐ Reduce energy costs
- ☐ Decentralise energy production
- ☐ Other: ________

Would you be willing to give surplus energy for free to
(multiple answers possible)

- ☐ A family member
- ☐ Someone in your neighbourhood/community you don't know
- ☐ A household that can't afford energy
- ☐ Someone in your neighbourhood/community you know
- ☐ A public facility in your community, i.e. school, swimming pool, youth centre
- ☐ A friend
- ☐ No, I would not give away my surplus energy for an indirect monetary return

Who would you be willing to give surplus energy to in exchange for an indirect monetary return?
E.g. free entrance to a public facility like museums or swimming pools, a household service like babysitting or gardening
(meerdere antwoorden mogelijk)

- ☐ A friend
- ☐ Someone in your neighbourhood/community you know
- ☐ Someone in your neighbourhood/community you don't know
- ☐ No, I would not give away my surplus energy for an indirect monetary return
- ☐ A public facility in your community, i.e. school, swimming pool, youth centre
- ☐ A household that can't afford energy
- ☐ A family member

In this section, we will be asking you about energy trading. Energy trading happens when you as the person responsible for the system generating electricity with photovoltaic panels or other sources, sell and purchase electricity from and to an electricity grid.

Imagine you had to decide between two options regarding the electricity trading in which your household participates. The three trading systems have varying characteristics regarding these six parameters:

- **CO2 emissions**: Electricity can be generated from different sources, which emit different amounts of CO2, which is one of the substances contributing to climate change. Electricity from renewable sources like PV or wind has relatively low CO2 emissions, while electricity generated from coal or gas has relatively high emissions.

- **Selling price**: The selling price determines for how much money you can sell one kilowatt hour of electricity.

- **Social connection with energy trading partner**: Currently, most people who produce their own electricity do not know where their surplus ends up when they feed it into the grid and to their provider. But there can be options where you can decide who you trade your energy with, for example a family member, friend or neighbour.

- **Additional effort**: Choosing an energy provider and selecting a trading system can entail some extra work on a monthly basis. For example for selecting energy trading partners, observing the ongoing trades or for configuring the technological device.

- **Improved efficiency**: Due to the nature of electricity grids, not all electricity can be utilized and therefore some is always lost. These losses vary depending on the location and management of the grid and can be minimized when additional measures are taken in an electricity trade.

- **Self-sufficiency**: Depending on the set-up of the electricity grid, you as an electricity producing household are dependent on grid operator and energy providers, who can decide over the nature of the electricity trade and have access to your data. Depending on the trading system, there is the possibility to increase the autonomy from them and to have more data privacy.

Some of the trading systems you will see are not currently available, but we would like you to imagine that they are available today. It is important that you answer in the way you would if you were actually deciding on a trading system.

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If these were your only options, which one would you choose?

(1 of 12)

	Option 1	Option 2	Option 3
CO2-emissions	Medium	High	Medium
Selling price	15 ct/kWh	10 ct/kWh	20 ct/kWh
Social connection with energy trading partner	Close (friends and family)	Direct (neighbour)	None (unknown)
Additional effort (time)	4 h/month	0 h/month	2 h/month
Improved efficiency	15%	0%	30%
Self-sufficiency	Medium	Low	Medium
	Select	Select	Select

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Next, I would like you to answer to a few statements to describe your attitude towards the environment, technology and your community.

	strongly disagree	disagree	neutral	agree	strongly agree
I am concerned about human behaviour and its impact on the climate and the environment.	◯	◯	◯	◯	◯
I always pay attention to ecological criteria when buying products and services.	◯	◯	◯	◯	◯
I feel a strong identification with my local community.	◯	◯	◯	◯	◯
There are many people in my local community whom I think of as friends.	◯	◯	◯	◯	◯
Learning how to use a technological device is easy for me.	◯	◯	◯	◯	◯
I enjoy exploring new technologies.	◯	◯	◯	◯	◯

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In this last section, I would like you to answer some questions about yourself. Be assured that all your responses are anonymous.

How old are you?

- ◯ younger than 25
- ◯ 25 to 35
- ◯ 36 to 45
- ◯ 46 to 55
- ◯ 56 to 65
- ◯ older than 65

What gender do you identify as?

- ◯ Female
- ◯ Male
- ◯ Third gender / non-binary
- ◯ Prefer not to say

What is the highest degree or level of education you have achieved?

- No formal education
- High school diploma
- Vocational training
- Bachelor's degree
- Master's degree
- PhD or higher
- Prefer not to say

Where is your household located?

- Large city
- Medium-sized city
- Small town
- Rural community

How many persons live in your household?

- 1
- 2
- 3
- 4
- 5 or more

What is your average yearly household net income?

- under € 20.000
- € 20.000 tot € 39.999
- € 40.000 tot € 59.999
- € 60.000 tot € 79.999
- over € 80.000

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0% 100%

Appendix C: DCE results

Table C.1. Average zero-centred part-worth utility scores of the whole sample.

Attribute	*Attribute levels*	*Average Utilities*	*Standard deviation*
CO_2 emissions	Low	79.90	83.39
	Medium	32.14	19.28
	High	-112.04	80.89
Selling price	10 €ct/kWh	-25.12	37.80
	15 €ct/kWh	-2.26	17.36
	20 €ct/kWh	27.38	41.27
Social connection	None (anonymous)	-20.44	19.08
	Direct (neighbour)	1.74	19.44
	Close (friends and family)	18.70	19.84
Additional effort (time)	0 h/month	45.41	49.39
	2 h/month	9.54	25.48
	4 h/month	-54.95	50.57
Improved efficiency	0%	-29.37	24.42
	15%	6.98	24.83
	30%	22.39	22.87
Self-sufficiency	Low	-17.85	34.08
	Medium	-7.52	14.44
	High	25.38	29.21

Table C.2. Average importance scores of the whole sample.

Attribute	*Average Importance (%)*	*Standard Deviation*
CO2 emissions	37.74	19.12
Selling price	12.58	9.79
Social connection	8.53	4.85
Additional effort (time)	19.60	13.54
Improved efficiency	11.42	5.17
Self-sufficiency	10.13	8.28

Appendix D: Prosumer characteristics - other responses

Table D.1. Other responses to the question "*What was/were the reason(s) you installed the renewable energy system at your home?".*

No.	Topic	Response
1	Economic	increasing value house
2		interesting businesscase
3	Technological	Awareness different sorts of energy sources / awareness energy flows
4	Self-sufficiency	Independence / self-reliance
5	Other	Installation was already there when we bought the house

Table D.2. Other responses to the question "*What was/were the reason(s) you chose your current energy provider?".*

No.	Topic	Response
1	Energy cooperative	energy cooperative
2		profit for local energy cooperative
3		cooperative, community based
4		citizen cooperative
5		cooperation
6		through the energy cooperative
7		it's my own cooperation!
8		local energy cooperative
9		also became member of energy cooperative Morgen Groene Energie (excluded liability)
10	Economic	favourable price/ good price
11		highest fee
12		good advice and good price/ quality ratio
13		A good *salderings*-regulation below 0
14		highest price per kWh
15		"Saldering" favorable
16		highest fee for giving energy back to the grid
17		High price for "teruglevering" [deliver your energy to the net]
18		best deal and local supllier
19	Experience	[I am] for years customer at current energy supplier
20		positive experience in my former house
21	Unique feature	Freedom to choose at what location the energy was produced
22		the Windcentrale delivers "winddelen". [A proof that you own a piece of a windmill and get energy. 15.000 People invested in 13 windmills and get energy. Administation by guarantees of origin, with an app you can see how many windenergy the windmills harvest
23		experience with electric driving
24		windenergy from the Netherlands
25		Possibility to share your own generated electricity with other customers and get energy from Existing supplier

26	No supplier	Since only a month solarpanel owner, therefore I have not searched for a energy suplier yet
27		No energy has been put into other … yet

Table D.3. Other responses to the question "*What was/were the reason(s) you became a member of an energy cooperative?".*

No.	Response
1	To use my expertise for a social purpose
2	When you buy wind parts from the wind power plant, you also become a member of the cooperative
3	To generate sustainable energy
4	I am one of the founders/ I myself was one of the first to be established in the Netherlands
5	for environmental reasons, because I make not much money with this investment. Investment in the Windcentrale
6	interesting volunteer work

Appendix E: Socio-economic characteristics of sample

Table E.1. Socio-economic characteristics of sample (N = 74).

		in %
Age	younger than 25	0.00
	25-35	4.05
	36-45	16.22
	46-55	28.38
	56-65	37.84
	older than 65	13.51
Gender	Female	12.16
	Male	85.14
	Third gender/Non-binary	1.35
	Prefer not to say	1.35
Education	No formal education	0.00
	High school diploma	2.70
	MBO (vocational)	13.51
	HBO (applied sciences)	28.38
	Bachelor's degree	8.11
	Master's degree	36.49
	PhD or higher	9.46
	Prefer not to say	1.35
Household location	Large city	21.62
	Medium-sized city	35.14
	Small town	12.16
	Rural community	31.08
Household size	1	5.41
	2	44.59
	3	18.92
	4	22.97
	5 or more	8.11
Household net annual income	under €20,000	5.41
	€20,000 - €39,999	14.86
	€40,000 - €59,999	35.14
	€60,000 - €79,999	20.27
	over 80,000€	24.32

Appendix F: Subgroup analyses of DCE

*Note: The difference is significant when the p-value is less than 0.05 (indicated with **) and less but still significant when it is less than 0.1 (indicated with *).*

Table F.1. Comparison of the DCE for the subgroups *energy cooperative member* (N = 34) vs. *no member* (N = 40).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		EC member	*Non-member*	*EC member*	*Non-member*
CO_2 emissions	Low	96.05	66.18	41.27	34.74
	Medium	31.11	33.01		
	High	-127.16	-99.19		
Selling price	10 €ct/kWh	-12.76**	-35.62**	8.84**	15.77**
	15 €ct/kWh	-0.26	-3.97		
	20 €ct/kWh	13.01**	39.59**		
Social connection	None	-18.29	-22.27	7.89	9.07
	Direct	1.96	1.56		
	Close	16.33	20.71		
Additional effort (time)	0 h/month	48.01	43.19	20.85	18.53
	2 h/month	8.52	10.41		
	4 h/month	-56.54	-53.60		
Improved efficiency	0%	-32.51	-26.69	11.81	11.10
	15%	6.13	7.69		
	30%	26.38	19.00		
Self-sufficiency	Low	-15.99	-19.43	9.35	10.79
	Medium	-7.31	-7.71		
	High	23.30	27.14		

Table F.2. Comparison of the DCE for the subgroups *willing to give surplus electricity for free* (N = 44) vs. *not willing* (N = 30).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		yes	*no*	*yes*	*no*
CO_2 emissions	Low	95.11*	57.59*	41.65**	32.00**
	Medium	29.42	36.13		
	High	-124.53*	-93.72*		
Selling price	10 €ct/kWh	-18.15*	-35.32*	10.62**	15.46**
	15 €ct/kWh	-2.93	-1.29		
	20 €ct/kWh	21.08	36.61		
Social connection	None	-20.99	-19.64	8.56	8.48
	Direct	-1.81*	6.94*		
	Close	22.80**	12.69**		
Additional effort (time)	0 h/month	38.38	55.70	17.64	22.46
	2 h/month	8.32	11.34		
	4 h/month	-46.70*	-67.05*		
Improved efficiency	0%	-31.49	-26.26	12.02	10.55
	15%	7.95	5.55		
	30%	23.53	20.71		
Self-sufficiency	Low	-17.10	-18.95	9.50	11.05
	Medium	-6.44	-9.12		
	High	23.54	28.06		

Table F.3. Comparison of the DCE for the subgroups *willing to give surplus electricity for an indirect monetary return* (N=56) vs. *not willing* (N=18).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores (%)*	
		yes	*no*	*yes*	*no*
CO_2 emissions	Low	85.48	62.56	39.23	33.10
	Medium	30.23*	38.09*		
	High	-115.70	-100.64		
Selling price	10 €ct/kWh	-21.56	-36.17	11.82	14.95
	15 €ct/kWh	-2.36	-1.95		
	20 €ct/kWh	23.92	38.12		
Social connection	None	-21.38	-17.51	8.66	8.11
	Direct	1.68	1.93		
	Close	19.70	15.58		
Additional effort (time)	0 h/month	39.52*	63.72*	18.64	22.56
	2 h/month	12.14*	1.48*		
	4 h/month	-51.65	-65.20		
Improved efficiency	0%	-30.56	-25.65	11.84	10.13
	15%	5.96	10.13		
	30%	24.60	15.52		
Self-sufficiency	Low	-16.02	-23.54	9.80	11.16
	Medium	-6.43	-10.93		
	High	22.45*	34.47*		

Table F.4. Comparison of the DCE for the subgroups *environmental attitude smaller than or equal to 3* (N = 13) vs. *larger than* 3 (N = 61).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		<= 3	*3 <*	*<= 3*	*3 <*
CO_2 emissions	Low	46.20*	87.08*	26.87**	40.05**
	Medium	34.08	31.73		
	High	-80.28*	-118.81*		
Selling price	10 €ct/kWh	-48.94**	-20.04**	19.13**	11.19**
	15 €ct/kWh	-11.04*	-0.39*		
	20 €ct/kWh	59.98**	20.43**		
Social connection	None	-29.39	-18.53	9.85	8.25
	Direct	4.68	1.11		
	Close	24.70	17.42		
Additional effort (time)	0 h/month	55.68	43.22	21.31	19.23
	2 h/month	10.46	9.35		
	4 h/month	-66.14	-52.56		
Improved efficiency	0%	-28.50	-29.55	12.71	11.15
	15%	16.37	4.97		
	30%	12.12	24.58		
Self-sufficiency	Low	-12.33	-19.03	10.13	10.13
	Medium	-14.40*	-6.06*		
	High	26.73	25.09		

Table F.5. Comparison of the DCE for the subgroups *technological attitude smaller than or equal to 3* (N = 5) vs. *larger than 3* (N = 69).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		<= 3	*3 <*	*<= 3*	*3 <*
CO_2 emis-sions	Low	40.34**	82.77**	20.70**	38.97**
	Medium	35.98	31.86		
	High	-76.31	-114.63		
Selling price	10 €ct/kWh	-46.25	-23.58	14.69	12.43
	15 €ct/kWh	18.06	-3.73		
	20 €ct/kWh	28.19	27.32		
Social con-nection	None	-6.47	-21.45	6.57	8.67
	Direct	-0.49	1.90		
	Close	6.97	19.55		
Additional effort (time)	0 h/month	96.82*	41.68*	30.82	18.78
	2 h/month	-12.69	11.15		
	4 h/month	-84.13	-52.83		
Improved ef-ficiency	0%	-23.33	-29.81	10.04	11.52
	15%	4.11	7.18		
	30%	19.22	22.62		
Self-suffi-ciency	Low	-41.24	-16.16	17.17	9.62
	Medium	-14.38	-7.03		
	High	55.62	23.18		

Table F.6. Comparison of the DCE for the subgroups *age under 46* (N = 15) vs. *46 and older* (N = 59).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		Under 46	*46 and over*	*Under 46*	*46 and over*
CO_2 emis-sions	Low	94.11	76.29	39.34	37.33
	Medium	37.15	30.87		
	High	-131.26	-107.15		
Selling Price	10 €ct/kWh	-19.26	-26.60	12.77	12.54
	15 €ct/kWh	-5.95	-1.32		
	20 €ct/kWh	25.21	27.93		
Social con-nection	None	-25.10	-19.25	8.08	8.64
	Direct	6.07	0.64		
	Close	19.04	18.61		
Additional effort (time)	0 h/month	51.07	43.97	20.57	19.35
	2 h/month	10.22	9.37		
	4 h/month	-61.29	-53.34		
Improved ef-ficiency	0%	-40.94**	-26.43**	11.89	11.30
	15%	17.14**	4.39**		
	30%	23.80	22.03		
Self-suffi-ciency	Low	-7.48*	-20.49*	7.35**	10.84**
	Medium	-10.68	-6.72		
	High	18.16	27.21		

Table F.7. Comparison of the DCE for the subgroups *net household income under €60,000* (N = 41) vs. *€60,000 and higher* (N = 33).

Attribute	*Attribute levels*	*Average Utilities*		*Importance Scores*	
		< €60,000	€60,000 ≤	< €60,000	€60,000 ≤
CO_2 emis-sions	Low	75.06	85.92	36.31	39.51
	Medium	32.38	31.84		
	High	-107.44	-117.75		
Selling price	10 €ct/kWh	-29.79	-19.30	14.07	10.73
	15 €ct/kWh	1.30**	-6.69**		
	20 €ct/kWh	28.49	26.00		
Social con-nection	None	-20.36	-20.55	8.53	8.53
	Direct	2.73	0.51		
	Close	17.63	20.03		
Additional effort (time)	0 h/month	45.69	45.05	19.71	19.46
	2 h/month	7.44	12.15		
	4 h/month	-53.13	-57.21		
Improved ef-ficiency	0%	-31.05	-27.28	11.28	11.61
	15%	8.02	5.68		
	30%	23.02	21.60		
Self-suffi-ciency	Low	-20.60	-14.43	10.10	10.16
	Medium	-5.76	-9.72		
	High	26.36	24.15		