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Factors influencing household demand-side flexibility: The case of the StrømFleks pilot project

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This thesis is worth 30 study points.

Abstract

Household demand-side flexibility plays a crucial role in integrating renewable energy to transit away from fossil fuels. The study investigates household behaviour and acceptance of demand-side flexibility using the StrømFleks pilot project in Porsgrunn, Norway, as the case study. Primary data was collected using a questionnaire to compare the participants with a group of non-participants. The Pearson chi-square, probit models and difference analysis are used to analyse the behavioural changes between the two groups. The empirical results show that the participating households have greater knowledge about flexible resources. Additionally, the participants demonstrate a higher willingness (85 per cent) to enter contracts to manage flexible resources compared to the control group (27 per cent). A flexible resource can be appliances, heating, water heaters and electric vehicles. These findings suggest that with knowledge and experience managing flexible resources, household demand-side flexibility can be utilised. Furthermore, the study highlights the need for attention to electric vehicle (EV) charging as a flexible resource, given that 70 per cent of the participants own an EV, but only 42 per cent charged off-peak. Economic incentives is a significant motivational factor, while societal, natural, and environmental factors play a role. Identified potential hindering factors include data and spatial privacy issues, as well as trust towards aggregators. Incentives to shift electricity consumption outside peak times are essential to free up grid capacity, and the study suggests the necessity for further pilot projects and more post-evaluations with scientific monitoring.

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Foreword

My interest in the topic of demand-side flexibility came along with renovations of my “new” house from the 1950s. It started with modernisation and energy efficiency measures such as insulations and energy-efficient windows. Over time, it progressed to changing the whole electricity system, adopting LED lights, energy-efficient appliances, floor heating, smart home technology, electric vehicle (EV), smart charging and, last autumn, solar panels on the roof. As I learned about the concept of demand-side flexibility, I realised I had become a prosumer. I monitor the electricity prices in the app on my phone and plan when to do laundry, start the dishwasher and use the smart charger to charge my car. Living in the same region as the StrømFleks pilot project, I was intrigued when I first heard about it. I wondered whether I would allow someone else to control the flexible resources in my home and whether I could trust them. Then I realised that I had already allowed someone else control of my smart EV charger, which works well as the car is fully charged every morning at 7 o’clock. Maybe the next step is to allow control of the other flexible resources in my home.

I would like to express my gratitude to Lede, particularly Ivan Schytte, the StrømFleks project leader and Mariona Zhuri, Portfolio Manager R&D, for the possibility of using StrømFleks as a case study for my research and for all your support along the way. I am also deeply thankful to Telemarksforskning for recognising the importance of my thesis topic and awarding me one of their master's grants in the spring of 2024. I extend my gratitude to Regine Sønderland Saga, one of their researchers, for her support. Special thanks to Eva Hagsten for her valuable guidance, particularly in the development of the questionnaire. I am sincerely grateful for all the support, guidance, and expertise in quantitative analysis from my supervisor, Professor Martin Falk. Furthermore, I would like to thank the respondents who took the time to complete the questionnaire. Additionally, I am grateful to my classmates for interesting sustainability discussions, particularly those from outside Europe who shed light on topics we often take for granted in Norway, such as basic human rights and literacy. Lastly, thanks to my partner, Espen Aasen, for all your support and hours of discussion.

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Malin Gudem Høiseth

1 Introduction

With the international agreement on climate change, the Paris Agreement (2015), the focus was placed on limiting global warming to 1.5 degrees by the end of this century. In order to achieve this goal, greenhouse gas emissions must be reduced (*The Paris Agreement | UNFCCC*, n.d.). Decarbonising and a transition to renewable energy sources like wind and solar are essential to reduce emissions (D'Ettorre et al., 2022; Spandagos et al., 2022). Electricity is generated and transmitted today in essentially the same way as when it was introduced more than 100 years ago (Dileep, 2020). For the most part, electricity operations are still vertically integrated, with centralised power plants at the top normally situated long distances away from the consumers at the end of the distribution line (Blumsack & Fernandez, 2012; Dileep, 2020). Unlike many other consumer goods, electricity must be produced at the same time as it is consumed. The electricity system has been maintained stable and reliable as the operators constantly oversee the supply and demand of electricity (Blumsack & Fernandez, 2012). Consumer preferences and demand for electricity have been taken for granted by operators as they have no real-time information. The operators have provided flexibility on the supply side by centralising the storage of fossil fuels and through peak power plants (Blumsack & Fernandez, 2012; Dileep, 2020; Kubli et al., 2018). Further, the grid is dimensioned for peak load at any given time, which is an inefficient design as peak load does not take place frequently (Dileep, 2020).

The power system and grid must be broadly upgraded in conjunction with the transition from fossil fuels to renewable energy and society's increased electrification (Statkraft, 2023). Electricity from renewable energy sources like wind and solar fluctuates depending on weather systems (Broman Toft et al., 2014). As it is difficult to store large quantities of electricity, unlike oil and gas, it is essential to balance supply and demand to maintain a stable power grid (Khajeh et al., 2020). Because of the increase in renewable energy sources, the need for flexibility in the grid will increase simultaneously, and various sources and solutions will cover this (Statkraft, 2023). If flexibility on the supply side decreases, demand response solutions, in which the reliability and efficiency of the electricity grid is maintained on the demand and customer side, will become increasingly important (Li et al., 2022).

The discussion about the future of the electricity grid is ongoing (Moretti et al., 2017; Sovacool et al., 2021). As the technology develops, the grid will evolve into a smart grid with the installation of smart meters and smart home technologies, and it is envisaged that consumers will become active participants, potentially providing demand-side flexibility to the grid (Blumsack & Fernandez, 2012; Dileep, 2020; Herndler et al., 2022; Parag & Sovacool, 2016). Demand-side flexibility refers to customers adjusting their electricity consumption (Hussain et al., 2023). Demand-side flexibility in the energy industry is not new, as it has been in place for large industrial and commercial customers for decades (D'Ettorre et al., 2022). What is new is the aim to include household customers and that all customer segments are involved more actively (D'Ettorre et al., 2022). Energy flexibility is the amount of load that can be shifted or reduced to different time periods (Hussain et al., 2023; Lezama et al., 2020). In a household, a flexible resource can be appliances, heating, ventilation, air conditioning, water heaters, and electric vehicles (EV)(Hussain et al., 2023; Lezama et al., 2020). Demand-side flexibility is seen to fulfil a crucial function for the inclusion of considerable volumes of renewable energy generation (D'Ettorre et al., 2022; Hussain et al., 2023; Li et al., 2022; Lu et al., 2020; Lund et al., 2017). Demand-side flexibility can be either implicit, where customers adjust consumption in response to price signals, or explicit demand-side flexibility, which is dispatchable and tradable in energy markets (Hussain et al., 2023).

The literature acknowledges the potential of demand-side response, yet few studies explore household customers' understanding and acceptance of demand-side flexibility. This study aims to enhance our understanding of household behavioural change and the factors that hinder or motivate the utilisation of household demand-side flexibility within the context of the smart grid. Currently, there are several pilot projects for flexible electricity distribution, such as StrømFleks, Euroflex and FlexOps (Lede, 2023a; Norflex, n.d.; SINTEF, 2022). Pilot projects serve as platforms to fabricate a new reality that can be studied and are viewed as political entities for shaping the future of societies (Ryghaug & Skjølsvold, 2021). This study empirically investigates whether participation in Lede's, a Norwegian distribution system operator, StrømFleks pilot project (2020-2023) on demand-side flexibility led to behavioural changes in the participating households' electricity consumption and utilisation of flexible resources (Lede, 2023a). A Norwegian case study is compelling due to Norway's predominantly renewable electricity sources, market-based electricity system, mature EV market, and smart grid infrastructure (Energifakta Norge, 2023; Jamil & Grønland, 2023). The following research questions have been formulated:

> RQ1: Does participation in a pilot project managing flexible resources change households' behaviour?
>
> RQ2: What factors motivate or hinder households in providing demand-side flexibility?

A comparative approach was applied, and primary data for the analysis were gathered through an online questionnaire of 33 of the 150 participants in Lede's StrømFleks project and a non-participant control group of 33 households in February-March 2024. The data was analysed using statistical methods to test for differences between the participants and the control group.

This research project is situated within the field of sustainability research, as its focus is on fostering sustainability rather than merely studying it (Franklin & Blyton, 2011). Increased understanding of household behavioural change and drivers and barriers towards a smart grid will have a social, economic, and environmental impact. This study relates to four of the United Nations' sustainability goals. By enhancing households' knowledge of electricity consumption and promoting energy efficiency and demand-side flexibility, the grid capacity can be optimised. Efficient use of the existing grid can provide capacity to customers needing electricity for their energy transition or business expansion. This aligns with SDG 7, "Ensure access to affordable, reliable, sustainable and modern energy for all". Furthermore, advancing smart grid technologies and making electricity a visible commodity is essential for maximising grid efficiency. This will accommodate the increase of renewable energy sources and facilitate the industries' energy transition. This supports SDG 9, "Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation". Facilitating the energy transition through efficient grid management also contributes to SDG 15, "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Transporting renewable energy to the end users, with the assistance of household demand-side flexibility, helps to maintain a stable and reliable grid while reducing greenhouse gas emissions and limiting climate change. Given the complexity of the smart grid, collaboration and co-creation are vital. Through such collaboration, SDG 17, “partnerships for the goals”, can be achieved.

Besides serving as a case study, the discoveries may hold relevance in a broader context. The study is significant in the domain of sustainability management as it contributes to the knowledge of management and policymakers in the energy sector related to the utilisation of demand-side flexibility. Furthermore, the study can offer valuable insights to regions and countries seeking to decarbonise and increase their renewable energy share.

The remainder of the study is structured as follows: In Section 2, the conceptual background and the context of the study are presented. The theoretical framework is introduced in Section 3. Section 4 reports the questionnaire design and methodological approach. The empirical correlation analysis and results are presented in Section 5. Section 6 starts with discussions related to RQ 1, and thereafter, RQ2 is discussed before the conclusion of the study is presented in Section 7.

2 Conceptual background

This section provides the conceptual background of the study. It begins by describing essential elements to the utilisation of household demand-side flexibility, followed by an introduction to the study's context.

2.1 The development of the smart grid

The terms "smart energy system" and "smart grid" are used in the literature. In this study, the focus is on the "smart grid", as the primary focus of this study is on the electricity sector and not a complete set of energy forms (Lund et al., 2017). Dileep (2020) describes the smart grid as "a transparent, seamless and instantaneous two-way delivery of energy, information and enabling the electricity industry to manage energy delivery and transmission better and empowering consumers to have more control over energy decisions" (Dileep, 2020, p. 2591). Smart grids are viewed as a promising way to deal with the challenges the electricity grid faces with the integration of renewable energies into the system (Rohde & Hielscher, 2021). Communication technologies and information are increasingly being used to react to changes in supply and demand, as they automatically monitor the energy flows. The constant monitoring enables the grid to integrate the electricity produced by solar and wind and the increased loads that occur because of society's increased electrification from, for example, electric vehicles (*Smart Grids and Meters*, n.d.). The smart grid incorporates a large scope of technologies like advanced sensors, actuator networks, storage components, incorporation of vehicle to grid and grid monitoring and control (Dileep, 2020; Raimi & Carrico, 2016a).

Smart meters are the core element, and their installation is the first step towards a smart grid as they enable bidirectional communication that integrates the consumers and the grid (Avancini et al., 2021; Ballo, 2015). Smart meters provide utility companies with useful information from the consumers that enables them to enhance the electricity supply, and they ease the management of metering and billing for utility companies (Geels et al., 2021). For consumers, smart meters give them the means to control home appliances and allow consumers to monitor their energy consumption on the utility provider's webpage or in an app on their smartphone (Avancini et al., 2021). When consumers get more information about their energy consumption, they can change their behaviour to save energy and spend less on energy bills (Avancini et al., 2021).

With a smart grid, unlike the traditional grid, where electricity flows one way, there is no longer a separation between utility companies and consumers, as consumers can also produce electricity for the grid (Lund et al., 2017). It allows consumers to become prosumers by producing their own renewable energy, for example, solar panels on the roof of their homes for their own use and with the possibility of selling the excess back to the grid (*Smart Grids and Meters*, n.d.).

The introduction of smart meters was met with great resistance from consumers in many countries, who were concerned about their privacy, safety and health (Raimi & Carrico, 2016a). By the end of 2021, 54 per cent of European households had installed smart meters (*Smart Grids and Meters*, n.d.). In Norway, the installation of smart meters was mandatory. Although there were some limited expressions of public concern, the fact that only 0.3 per cent of the households, plus an additional 0.2 per cent citing medical grounds, choose to opt out suggests that the Norwegian population had limited concerns about the installation of smart meters (Geels et al., 2021). The distribution system operators were responsible for installing smart meters, and the cost was paid for by the consumers through an increased transmission tariff (Ballo, 2015). Implementation of smart meters in Norway was finalised in the autumn of 2022, as 98.8 per cent of all customers in the low-distribution network have smart meters installed (Jamil & Grønland, 2023). The implemented smart meters automatically transmit hourly consumption values and the distribution system operators have started to prepare for 15-minute intervals (Jamil & Grønland, 2023).

2.2 Smart home technology

Smart home technology consists of sensing and communication devices that communicate with each other (Gram-Hanssen & Darby, 2018; Shin et al., 2018). Gram-Hansen and Darby (2018) have defined «smart homes as homes that contain a complex communications network, allow for remote monitoring and control, and provide services to both occupants and electricity system operators" (p. 13). Therefore, smart home technologies support the development of the smart grid and are essential for consumers to become prosumers (Sovacool, 2021). Concerning energy consumption, these technologies can be used to control and automate lights, heating, air conditioning, hot water tanks, and home appliances such as dishwashers, ovens, and fridges via apps on smartphones or touchscreen devices (Shin et al., 2018; Tirado Herrero et al., 2018). The usage of smart home technology can lead to behavioural changes as it provides feedback to enhance changes in the household's utilisation of energy and affect the well-being of the inhabitants (Sovacool, 2021). Nikou (2019) goes on to say that smart home technology "provides households with e.g., comfort control and convenience" (p.1).

Installing and using smart home technologies broadly in society involves social risks, as installation and use require technical knowledge, skills, and financial investment (Sovacool, 2021). This might lead to vulnerability and social exclusion for some classes of people and raise the issue of security and privacy risks in general (Sovacool, 2021). Previous research reveals that adopting smart home technologies has taken longer than expected (Billanes & Enevoldsen, 2022; Gram-Hanssen & Darby, 2018; Shin et al., 2018; Sovacool, 2021).

2.3 Prosumers and demand-side flexibility

A consumer "buys goods or services for their own use" (Cambridge Dictionary, 2024a), and customers in the electricity market can be industries, businesses and households (D'Ettorre et al., 2022; Parag & Sovacool, 2016). With technological advancement, the installation of smart meters, and the development of the smart grid, the traditional passive paying consumer in the electricity market turns into an active consumer (Parag & Sovacool, 2016). The consumers in the electricity markets become "prosumers" as they offer services to the grid by producing renewable energy, performing demand reduction, shifting their load of energy usage and providing decentralised storage available by investing in batteries or through flexible heating behaviour that provides heat reserves (Kubli et al., 2018; Michaels & Parag, 2016; Parag & Sovacool, 2016; Sajn, 2016; Smale et al., 2019). Parag and Sovacool (2016, p. 1) see two paths for the prosumer, either as "off-grid and self-sufficient" or "connected to a grid". When prosumers shift their energy usage load, their demand reduction has value for the energy industry, providing decentralised flexibility as an alternative to the centralised flexibility traditionally provided by utility companies (Kubli et al., 2018; Sajn, 2016). Flexibility can be differentiated according to the needs, including flexibility for power, energy, transfer capacity, and voltage (Hillberg et al., 2019). Impram et al. (2020, p. 10) define “flexibility in power systems is the ability to provide supply-demand balance, to maintain continuity in unexpected situations, and to cope with supply-demand uncertainty”.

There are two types of demand response programs: one is price-based, and the other is incentive-based (D’Ettorre et al., 2022; Niesten & Alkemade, 2016). In the price-based program, the prosumers are exposed to electricity prices and network tariffs that vary over time. In the incentive-based program, prosumers receive incentives, like, for example, payment or green electricity deals, to reduce their own loads or allow a third party to partly or directly control the household’s load management (D’Ettorre et al., 2022; Niesten & Alkemade, 2016).

2.4 Electric vehicle’s role in the smart grid

The transport sector worldwide is responsible for 24 per cent of emissions, and more than half of these emissions come from passenger cars, 57 per cent in the European Union (Künle & Minke, 2022). EVs play an important role in reducing greenhouse gas emissions, and many countries have set EV penetration targets for the years to come (Noel et al., 2020; Sathiyan et al., 2022; Yang et al., 2023). EVs are “light private passenger battery electric vehicles or plug-in hybrid electric vehicles” (Noel et al., 2020, p. 2). The increasing number of EVs leads to increased demand for charging at home, which, again, will put further strains on the electricity grid (Sørensen et al., 2021). The prevalence of EVs also holds a positive potential as EVs can play a significant role in developing the smart grid as they can partake in demand response programs, adjust their charging according to signals, and reduce pressure during peak demand periods (Sørensen et al., 2021). Further, if the EVs are equipped with Vehicle-to-Grid technology (V2G), they can store energy in the battery and supply it back to the grid during peak times or grid emergencies, helping to stabilise the grid (Mehdizadeh et al., 2024).

2.5 Aggregators and co-creation

With the transition from a traditional grid to a smart grid, there is a development in “new business models and digital infrastructures in the form of “energy platforms”

(Smale & Kloppenburg, 2020, p. 1). The energy platforms can be either locally self-sufficient or integrated with the grid (Smale & Kloppenburg, 2020). Prosumer households are small independent actors that might not have the knowledge or ability to trade their flexibility in the market. With grid integration, the aggregator is an emerging actor in the energy market. An aggregator will bundle and manage the flexibility of all the small prosumers, monitor the energy platforms and serve as an intermediary between the suppliers and buyers of demand-side flexibility (Kerscher & Arboleya, 2022; Lu et al., 2020; Rohde & Hielscher, 2021; Smale & Kloppenburg, 2020). Further, an aggregator can be a utility company, an electricity supplier or a new third-party company (Lu et al., 2020; Rohde & Hielscher, 2021; Smale & Kloppenburg, 2020). Different stakeholders will have to collaborate to co-manage the grid to realise the potential of demand-side flexibility, and the prosumers play an essential role (Kotilainen et al., 2019; Kubli et al., 2018; Smale et al., 2019). The business model of the energy market is changing from company-centric value creation to value co-creation between prosumers and aggregators (Prahalad & Ramaswamy, 2004). For the aggregator to fulfil its role, it should take the following responsibilities towards the prosumer: understand the prosumer potential of demand-side flexibility, automated control and communication through the smart grid, establish a scheduling framework and provide incentives (Lu et al., 2020). The prosumers will be obliged to provide the information the aggregator needs, including a forecast of their total electricity consumption (Lu et al., 2020). For the transition to a smart grid to be successful, value must be created for the prosumers, and aggregators must capture value as bundles of flexibility can be sold in the market (Niesten & Alkemade, 2016). The flexible resources can be traded in marketplaces like Piclo and Nodes (Nodesmarket, 2023; Piclo, 2023).

2.6 Collaboration and trust

Collaboration "refers to any situation in which people are working across organizational boundaries towards some positive end" (Huxham & Vangen, 2005, p. 4). There are several bases for collaborative advantages, and for the pilot project, the main basis is mutual learning (Huxham & Vangen, 2005). If prosumers and aggregators are to collaborate to provide flexibility to the grid, the basis for the collaboration would be access to resources, as the partners would not be able to achieve the goal with their own resources (Huxham & Vangen, 2005). Collaboration between partners can have an advantage as they achieve the desired synergistic outcome from their collaboration, or there can be obstacles in the way of fulfilling the collaboration goal (Huxham & Vangen, 2005). Some obstacles that collaborators can face are lack of trust, divergent aims, power differences, the inability to handle conflicts and other factors (Savage et al., 2010).

Beckert (2006) states that “markets are the core institution of capitalism” (p. 318), and he says that trust between exchange partners is one essential element in most markets. Choices involve uncertainty, and humans use trust in their decision-making process (Greenberg, 2014). Elster defines trust as the act of "lower one's guard, to refrain from taking precautions against an interaction partner" (Elster, 2015, p. 335). From an economic aspect, trust between exchange partners leads to lower transaction costs, while mistrust will increase transaction costs (Rothstein & Holmberg, 2020). Trusting behaviour “depends on social, structural, institutional and cognitive preconditions that facilitate trust” (Beckert, 2006, p. 319). “It is not only important whether people think that the parties involved have sufficient knowledge and expertise, but also how these parties have performed in the past, whether people perceive them as open, honest, and taking their interests into account, and whether people think these parties endorse values similar to their own” (Steg et al., 2015). In relation to the energy transition and the development of the smart grid, households' trust towards the different stakeholders involved can affect their willingness to install smart meters and smart house technology, become prosumers and make agreements with aggregators to utilise flexible resources (Michaels & Parag, 2016).

2.7 Context of the study

The study begins by setting the contextual background of the case with a brief overview of the Norwegian context. Norway relies on renewable energy, is an early adopter of a market-based electricity system, has a mature EV market, and has completed the installation of smart meters. Furthermore, Telemark County is identified as an industrial region with a high demand for renewable energy and challenges with grid capacity. Within this framework, the case of the StrømFleks pilot project is introduced.

2.7.1 The Norwegian context of the study

In Norway, the free-market forces are important (Britannica, 2024). When Norway introduced a market-based electricity market for all customers in 1991, it was one of the first countries in the world to do this (Energifakta Norge, 2023). In 1993, Statnett Marked was established as an independent power exchange, and this developed into Nord Pool in 1996 as Norway and Sweden established a joint power exchange. Nord Pool became the first international electricity exchange when the other Scandinavian countries and later European countries joined. Nord Pool works for a single integrated European power market and promotes an efficient electricity market where renewable energy is integrated (Nord Pool, 2023).

Hydroelectric power production in Norway was the world's largest per capita at the start of the 21st century (Britannica, 2024). In 2023, the Norwegian power plants produced about 156 terawatt hours (TWh); about 88 per cent of this electricity is produced by hydropower plants and about 11 per cent by wind farms (Energifakta Norge, 2023). As the Norwegian energy system is mainly based on hydroelectric power production, it is also weather-dependent (Statnett, 2024c). As a result, the production capacity varies in different parts of the country. For this reason, the electricity grid system is divided into five price areas: Eastern Norway (NO1), Southern Norway (NO2), Central Norway (NO3), Northern Norway (NO4) and Western Norway (NO5) (Statnett, 2024b). The flow of electricity within and across the different price areas is limited by grid capacity, and the price of electricity is adjusted according to production and demand (Statnett, 2024b). Adjusting the price level of electricity is used by the electricity producers to reduce consumption (Statnett, 2024c).

The electricity grid in Norway consists of three levels: firstly, the transmission grid forms a nationwide network managed by Statnett, facilitating the connections between electricity producers and consumers (Norwegian Ministry of Energy, n.d.). Next, the regional distribution grid serves as the intermediary between the transmission grid and can include production and consumption (Norwegian Ministry of Energy, n.d.). Lastly, the local distribution grid delivers electricity to small-end customers (Norwegian Ministry of Energy, n.d.).

Norway has a population of 5,533,582, and in 2023, there was a total of 2.694.301 households in the country, and 65 per cent of the households own the home they live in

(*Statistisk sentralbyrå*, 2024). Of these, 48 per cent of the households are villas, and the remaining is a mix of semi-detached houses, terrace houses, flats, and other types of homes (*Statistisk sentralbyrå*, 2024). According to The Energy Commission, about two-thirds of the household's energy usage goes to heating rooms, about 12 per cent goes to heating tap water, and a bit more than 20 per cent goes to electric equipment like fridges, washing machines, and lighting (Miljødepartementet, 2023). The Norwegian dependency on electricity for heating of buildings has increased as heating with oil products was banned in 2020 ('Energikommisjonen', 2022).

Norway has the highest EV share globally (Künle & Minke, 2022; Orlov & Kallbekken, 2019; Sørensen et al., 2021). The EV market in Norway has been promoted since the early 1990s with several appealing incentives from the national and local governments, and it can now be described as a well-matured market (Ryghaug & Skjølsvold, 2021; Sathiyan et al., 2022; Schulz & Rode, 2022; Yang et al., 2023). In general, it is more expensive to charge an EV in public fast charging locations than it is to charge at home hence 80 per cent of EVs are charged at home (Schulz & Rode, 2022). For households primarily charging their EVs at home and consuming 18000 kilowatt-hour (kWh) per year, the EV accounts for 12 per cent of the consumption (Statistics Norway, n.d.-e). A study from 2021 found a difference in charging habits between EV owners who have a private charging point and those who share points, for example, in apartment buildings (Sørensen et al., 2021). EVs at private charging points were connected for 12,8 hours, while at the shared points, they were connected for 6,5 hours; in addition, EVs at private points were charged 3,5 times more frequently than those at shared points (Sørensen et al., 2021). Therefore, private charging sessions have longer non-charging idle time and a greater potential for flexibility than shared points (Sørensen et al., 2021).

In 2022, Norway's electricity consumption by industries and households, excluding industries on the Norwegian continental shelf, accounted for 126 TWh. The households consumed 36 TWh of electricity, and this was a decrease of 6 TWh from 2021 (see Figure 2 - 1).

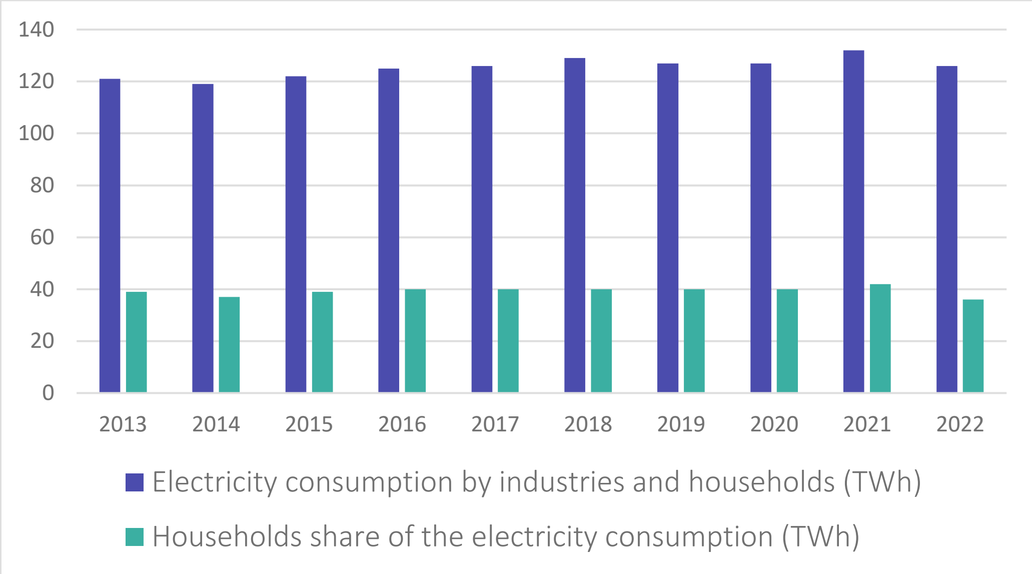

Figure 2-1 Electricity consumption by industries and households in TWh.

Source: Table 11558, Statistics Norway (Statistics Norway, n.d.-c).

Historically, Norway has had low electricity prices, and consumers have not taken many measures to limit their energy consumption (Throne-Holst et al., 2008). The decrease in household energy consumption from 2021 to 2022 can be related to consumer behavioural change due to the steep increase in electricity prices in this period (see Figure 2-1).

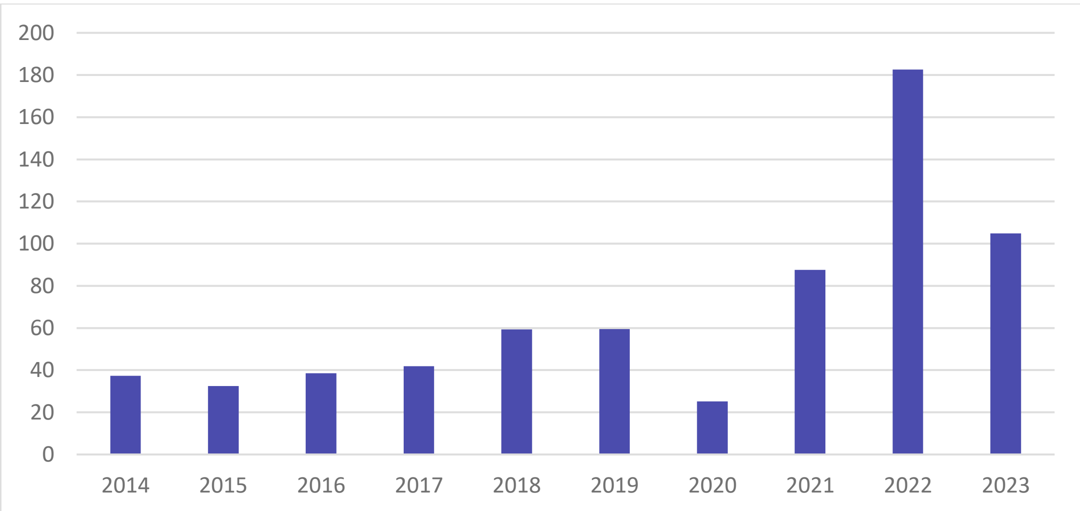

Figure 2–2 Electricity price including tax (øre/kWh).

Note: 1 NOK is subdivided into 100 øre.

Source: Table 09007, Statistics Norway (Statistics Norway, n.d.-a).

Because of the steep increase in electricity prices, the Norwegian government launched an electricity support package for households in December 2021. From September 2023, the compensation is calculated by the hour when the price rises above 73 øre/kWh; for those hours, households receive 90 per cent in support (NVE - RME, n.d.). The support is deducted from the monthly grid rental bill, and the electricity support will run until the end of 2024 (NVE - RME, n.d.). Figure 2–3 displays the prices of electricity, including grid rent and taxes for household customers and the price with the support deducted by quarter from 2017 until December 2024.

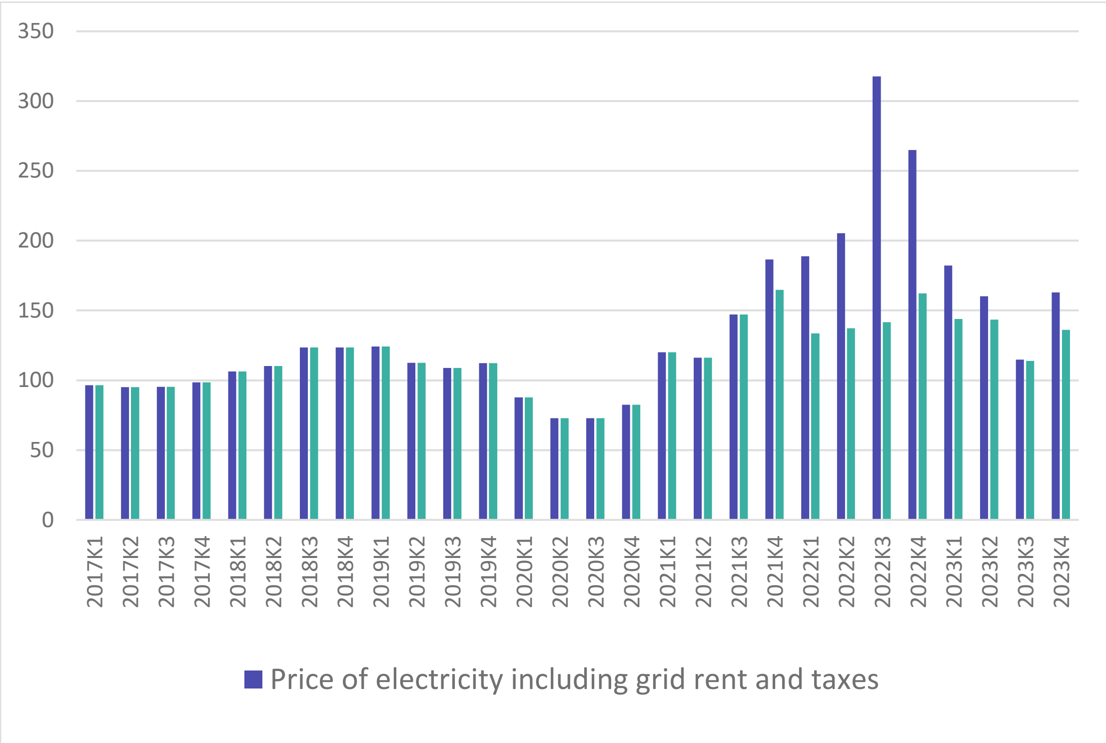

Figure 2–3 Electricity prices, including grid rent and taxes, for households by quarter.

Note: Prices are displayed in øre/kWh, 1 NOK is subdivided into 100 øre.

Source: Table 09387, Statistics Norway (Statistics Norway, n.d.-b).

As the electricity prices reached an all-time high in 2022, it triggered increased concerns among customers and sparked discussions about electricity suppliers in society (EPSI Rating, 2023). Concurrently, the reputation of the electricity industry reached its all-time low, listing at 32 points compared to the highest in 2015 at 62 points (Livgard, n.d.). Allegations surfaced that electricity suppliers were violating customers' rights and tricking them into paying a higher price for electricity than necessary (Kaldestad, 2023). The Norwegian Customer Council guidance service reported a 70 per cent increase in inquiries related to the electricity industry in 2022 compared to the previous years (Kaldestad, 2023). This indicates that trust in aggregators can be a barrier to trading demand-side flexibility parcels in the market.

The Ministry of Energy's white paper «Meld.St.36 (2020-2021), "Energy for labour – long-term value creation from Norwegian energy resources" (Energi til arbeid – langsiktig verdiskapning fra norske energiressurser) states that Norway aims to reduce greenhouse gas emissions by at least 50 per cent and up towards 55 per cent by 2030 and become a low emission society by 2050 (Energidepartementet, 2021). To achieve these goals, there is a need to increase electrification and a well-functioning distribution grid. The capacity in the grid should be utilised so that the needed electrification of the society can be done within the existing grid (Energidepartementet, 2021). In addition to the white paper, two government bodies that published their governmental inquiry in 2023 proclaim the same regarding electrification and utilisation of the existing grid. The Energy Commission (Energikommisjonen) was mandated to map the energy needs and suggest ways to increase energy production so that the Norwegian population and industry can still obtain renewable and enough energy (Norges offentlige utredninger, 2023). The 2050 Climate Change Committee were appointed to investigate the choices the country faces to achieve the goal of being a low-emission society by 2050 (Miljødepartementet, 2023). Among the suggested measures in these reports is to make houses and buildings more energy-efficient and end users, like households, can be prepared to become active participants on all levels in the energy system. To reduce the peaks in energy consumption, new technologies can be utilised to make usage more flexible in buildings and by consumers. Further, utilising flexibility is viewed as a possibility to balance the grid (Energidepartementet, 2021; Miljødepartementet, 2023; Norges offentlige utredninger, 2023). It is pointed out that strong measures for energy efficiency are necessary; these measures are difficult to achieve with low energy prices. High energy prices that fluctuate, enhanced competence on all levels, technical solutions to manage usage, and behavioural change in the population is essential (Miljødepartementet, 2023). Households are viewed as small actors, and it is important that they contribute, but they perform energy-efficient measures without expert competence. One means of action can be that aggregation of all the small flexible resources in households can be automated

(Norges offentlige utredninger, 2023). The role of aggregators is in progress, and new regulations related to aggregation will be looked into (Energidepartementet, 2021).

2.7.2 The Telemark County context of the study

Telemark County is located in the southeastern part of Norway and consists of 17 municipalities, with 177 100 inhabitants (Selland et al., 2024). The county's population is centred in the Grenland region, which consists of four municipalities around the Skien fjord area: Skien, Porsgrunn, Bamble, and Siljan. Telemark County has a long history of hydroelectric power production and industrialisation (Energidepartementet, 2019). Herøya, in Porsgrunn, is one of Norway's largest industrial clusters, compromising approximately 80 businesses and employing 2500 workers (Herøya Industripark, n.d.-b). The electricity consumption of these businesses accounts for a grid capacity of 200 megawatts (MW) (Herøya Industripark, n.d.-b; Mæhlum & Lundbo, 2024). The Grenland industry has an ambitious goal to become "the world's first climate-positive industry region" by 2040 (Powered by Telemark, n.d.). To achieve this, it needs to decarbonise, and one way to do this is to electrify and utilise renewable energy sources. The director of Herøya Industripark (Herøya Industrial cluster), Sverre Gotaas, says getting enough electricity for projects and industries that would like to establish in the Industrial cluster will be an issue until Statnett can expand the transmission grid in the region, earliest in 2030 (Hella, 2023; Herøya Industripark, n.d.-a). Grenland is one of the areas in Norway where the situation of the transmission grid is the most critical, as the possibility of reserving more capacity beyond 5 MW has to be considered (Statnett, 2024a). Statnett prioritises the identified critical areas, but increasing the capacity in the transmission grid takes from 3 to 10 years, depending on whether it is to increase transformer capacity or build a new grid (Statnett, 2024a). Lede, the distribution system operator in Telemark, puts actors related to the Herøya industrial cluster who ask for more than 5MW on a waiting list to get grid capacity to electrify, establish or expand their business, and in total, they acquire around 400 MW (Westhrin, 2024).

Other industries seeking to establish themselves in the region also rely on electricity. On the 7th of February 2024, Google confirmed the establishment of a new data center in Skien. When the first stage is operational in 2026, it has been allocated 240MW grid capacity, which corresponds to a yearly consumption of 1.7 TWh (Google

Norge, n.d.; Sagen, 2024). Google would like to develop the center further and has acquired Statnett for another 840 MW (Rivrud, 2024). In a neighbouring municipality to Grenland, Nome, there is another industrial cluster pending, mining for rare earth elements (REE) at Fensfeltet, one of Europe's largest deposits (Nome municipality, 2023). The REEs are critical for the green transition as the minerals are used in, for example, computers, wind turbines, and batteries (Nome municipality, 2023). Today, the extraction and production of REE minerals are mainly controlled by China. Therefore, the EU now classified REEs as strategic raw minerals and focus on the production of these minerals in Europe (Nome municipality, 2023). If the extraction and production of REEs in Nome starts up, the municipality would like to create “Fensfeltet Green Mineral Park” to utilise as much of the ore as possible in one location (Arvesen, 2024). The size of the “Fensfeltet Green Mineral Park” can ultimately become similar to the Herøya industrial cluster regarding area and electricity consumption (Arvesen, 2024).

Telemark belongs to price region NO2, and Figure 2-4 presents the electricity consumption by consumer groups in NO2 in July 2023 and January 2024.

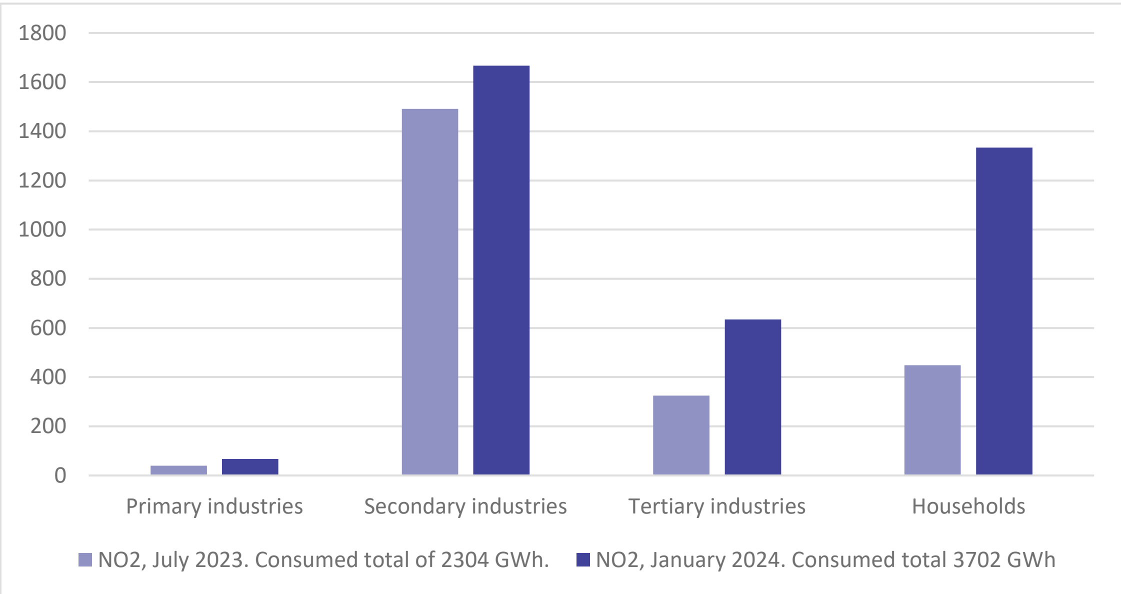

Figure 2-4 Electricity consumption by consumer groups in July 2023 and January 2024.

Note: Consumption displayed in GWh. Primary industries: agriculture; Secondary industries: industry and mining, oil extraction, construction and civil engineering, and power and water supply; Tertiary industries: service sector, including public administration.

Source: Table 14092, Statistics Norway (Statistics Norway, n.d.-d).

In July, the households' energy consumption (19 per cent) was quite modest compared to the secondary industries (65 per cent) as there is limited need for heating. In the coldest winter month, January, the households' electricity consumption tripled from 449 gigawatt hours (GWh) in July to 1334 GWh (Harstveit, 2023). 1334 GWh equals 1,33 TWh. The secondary industries still consume the most electricity, at 45 per cent in January, but household consumption increased to 36 per cent of the total electricity consumption in the price region NO2. This shows that even small independent actors, like households, because they are so many compose a large quantity of electricity consumption, especially in the coldest months.

The grid in Telemark is already under pressure, and it has reached its limit for large businesses to establish or conduct the energy transition to renewable energy sources within a short time frame (Statnett, 2024a; Westhrin, 2024). Hence, it is necessary to investigate solutions to utilise the existing grid as efficiently and as quickly as possible.

2.7.3 The StrømFleks case study

Eight large-scale pilot projects supported by Enova are referred to in The Ministry of Energy's white paper «Meld.St.36 (2020-2021), "The pilot projects shall develop and test different ways to develop new flexibility resources and focus on the interaction between different technologies, stakeholders, design and regulations" (Energidepartementet, 2021, p. 68). Enova is a Norwegian government enterprise owned by the Ministry of Climate and Environment, and its purpose is to promote the reduction of energy consumption and energy-efficient practices and encourage the use of new energy-reducing technologies and environmentally friendly energy production (Enova, n.d.-b).

Skagerak Energi AS is a regional energy group based in Porsgrunn, Norway. The energy group consist of eight subsidiary companies mainly fully owned by Skagerak Energi AS, including Lede AS, one of Norway's largest distribution system operators (*Skagerak Energi - Forside*, n.d.). Lede distributes about 7 TWh of electricity through their 18.115 kilometres of regional distribution grid to more than 216.000 households, commerce and large industrial customers in the counties of Telemark, Vestfold and Buskerud (*Om Lede*

- *Lede*, n.d.). Lede conducted one of the eight large-scale pilot projects related to flexibility, StrømFleks (2020-2023), that explored a more efficient use of the electricity grid through energy management and a more flexible use of electricity (Enova, n.d.-a; Lede, 2023a). StrømFleks consists of four parts: BoligFleks (HouseholdFlex), ByggFleks (Commercial Building Flex), and BilFleks (EV Charging Flex) are different customer segments, while the fourth part is a new platform solution which combines the different customer segments into a portfolio (Lede, 2023). If the platform solution proves effective, Lede will hand it over to an aggregator for further implementation, as Lede is a distribution system operator in a monopoly situation.

For the StrømFleks pilot project, the following stakeholders were identified (see Figure 2-1): Lede was the project owner and the one who applied and got the funding of 5.311.600 NOK from Enova approved in 2019 (Enova, n.d.-a). SINTEF Energi AS, an applied research institute, helped Lede analyse the data produced when the flexible resources were disconnected. Aidon provided the Smart Energy Service Devices. ENFO/Flextool is the platform for flexibility by delivering software and hardware to collect measurements. Futurehome delivered the smart home technology, app and support, while electricians from Herøya Elektro installed the technology. The different customer segments where the flexible resources were shifted comprised 150 households, Vestfold County, represented by a school in Horten Municipality and Format Eiendom provided the electrical vehicle charges in one of their commercial buildings. In addition, society is a stakeholder as demand-side flexibility can facilitate more renewable energy sources and, hence, the energy transition, freeing up capacity in the grid to industries that require electricity for their establishment and job creation. And lastly, nature is a stakeholder, as better utilisation of the grid will reduce the need to expand and build new grids.

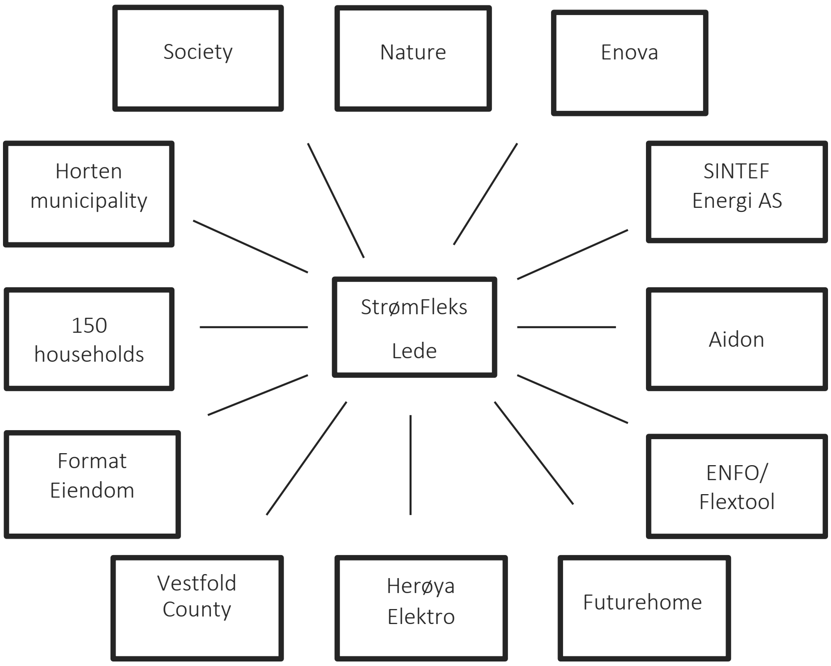

Figure 2-5 The stakeholders in Lede's StrømFleks project.

Source: (StrømFleks workshop, 2024; *StrømFleks - Lede*, n.d.)

This study will focus on BoligFleks and the project's impact on household behaviour changes, and BoligFleks will be referred to as StrømFleks for the remainder of this paper. StrømFleks consisted of 150 volunteer households within one residential area in Porsgrunn, all connected to one power grid station with high effect. To participate in the pilot project, the participating households needed to have smart home technology installed (Lede, 2024). Of the participating households, 27 already had smart home technology installed. But for "communication" in the project, all the participants needed the same smart home technology installed. Hence, all 150 participating households had smart home technology from Futurehome installed at a cost of 14.390 NOK per household covered by the project (M. Zhuri, personal communication, 7 May 2024). By utilising smart home technology and the included app, the household's knowledge and experience can increase and lead to more efficient electricity usage, and it could give them the possibility to save money (Lede, 2024). Through the app, the participants would also choose which flexible appliances, like water heaters, heat pumps, panel heaters and floor heating, in their homes that would be controlled as part of the project. Lede was permitted to turn off flexible resources in the household for one hour during peak times in the morning and the afternoon to monitor the effect and the rebound effect on the grid (Lede, 2023). Originally, the project was scheduled to run from 2020 until 2022. However, because of the sudden increase in electricity prices and the introduction of the new grid tariff during the project period, the project was extended for a year and ended in the summer of 2023 (Lede, 2024). When the project was extended, 10 of the households opted out and 140 continued in the project. The StrømFleks project lasted until the summer of 2023.

3 Theoretical framework and hypotheses

This section provides the theoretical framework for understanding behaviour changes related to participating in a demand response pilot project, and factors that motivate or hinder household utilisation of flexible resources. The study is grounded in normative stakeholder theory, which emphasises the importance of considering interests beyond the financial and includes morals and ethics (Freeman & McVea, 2005). It offers a comprehensive framework for understanding the interests and concerns of key stakeholders with the objective of utilising household demand-side flexibility in a smart grid system. Examining stakeholder dynamics and insights can help to overcome barriers; the study aims to identify potential hindrances and motivations that can facilitate the successful adoption of demand-side flexibility initiatives. Central to this approach is the importance of creating value for all stakeholders involved; considering the needs and perspectives of stakeholders can lead to using the advantage of demand-side flexibility to incorporate renewable energy and create a resilient grid. Furthermore, the study investigates behaviour change within the context of household electricity consumption and demand-side flexibility to uncover key factors influencing consumer decisions and behaviour related to electricity usage. Lastly, the section introduces the hypotheses of the study.

3.1 Stakeholder Theory

Stakeholder management has been used in strategic management to look after and satisfy the different parties with a stake in a business (Freeman & McVea, 2005). Freeman and McVea (2005) define a stakeholder as “any group or individual who is affected by or can affect the achievement of an organisation’s objectives” (p. 183). For a business to be successful and survive in the long run, the interest of the key stakeholders should be integrated into the business purpose, and it is important to understand how the business affects its surroundings and how the surroundings will affect the business (Freeman & McVea, 2005). According to Freeman and McVea (2005), morality and ethics should be incorporated into business, and values shared with key stakeholders should be included in the strategic management process, as stakeholder relationships cannot be taken for granted. With today's rapidly changing world, Freeman and McVea (2005) go on to propose that “as the business world becomes ever more turbulent, interconnected and as the boundaries between firms, industries, and our public and private lives become blurred, a stakeholder approach has more and more to tell us about values and value creation” (p. 188).

The prosumers, as a stakeholder in a smart grid system, hold multiple roles as they consume electricity; if they have solar panels installed, they can produce electricity for self-consummation and sell the excess to the grid, and they change their behaviour and shift the household flexible resources to free up capacity in the grid (Mihailova et al., 2022). With consumers turning into prosumers and co-creators, together with aggregators, to utilise flexibility in the energy market, the stakeholder relationship between the two is interconnected, and the boundaries between business and private lives are blurred. This new stakeholder relationship challenges the previous organisation-centred stakeholder relationship by becoming more issue-centric (Mihailova et al., 2022; Olkkonen et al., 2017). To utilise flexibility, there is a need for the prosumer and the aggregator to move in the same direction, or else the delivery of household flexibility to the market might be hindered (Olkkonen et al., 2017).

This study will use stakeholder theory to analyse the drivers and barriers to utilising household flexibility as an issue-centric case, with the prosumers and aggregators as the centre instead of an organisation. Utilisation of household flexibility will not be possible without co-creation between the two. Involving the prosumers in the value proposition of the business model for utilising householder flexibility can ensure that participation is appealing to the prosumers (Kotilainen et al., 2019; Mihailova et al., 2022). Stakeholder management is important as it can improve cooperation in the complex energy system and help understand the dynamics of the energy transition (Marcon Nora et al., 2023).

3.2 Behavioural change

To utilise the potential of a smart grid and demand-side flexible resources, there is a need to look further than solely on technology development and study the impact of the social dimensions, as human behaviour affects the individual's acceptance of technology and energy demand (D’Ettorre et al., 2022; Lazowski et al., 2018; Mohseni et al., 2021; Sovacool, 2014; Spandagos et al., 2022). Behaviour is «the way a person, an animal, a substance, etc. behaves in particular situations or under particular conditions" (Cambridge Dictionary, 2024b). Individually, human behaviour does not have a large impact, but combining all human behaviour has a huge impact on the planet (Gifford & Nilsson, 2014). It would benefit the planet and humans to change to more pro-environmental behaviour, and several factors influence this change (Gifford & Nilsson, 2014).

Understanding the individual-level motivational factors is important to implement initiatives for behaviour change (Perri et al., 2020). Several personal and social factors influence and result in pro-environmental behaviour; hence, it is essential to study the households' socioeconomic groups and behavioural factors (Gifford & Nilsson, 2014). Relating to gender, women report stronger environmental attitudes and behaviours than men (Gifford & Nilsson, 2014). Previous studies provide mixed evidence regarding age's importance as a behavioural factor (Niamir et al., 2020). Moreover, the likelihood of investing in energy-efficient measures increases with home ownership, as homeowners tend to prioritize such investments more than renters (Niamir et al., 2020).

Without knowledge about environmental issues or energy use, it is challenging to make potential positive behavioural changes (Gifford & Nilsson, 2014). Previous studies have shown that knowledge predicts more pro-environmental behaviour, and "individuals with more education in general are more concerned about the environment" (Gifford & Nilsson, 2014, p. 142). "Environmentalists tend to be middle- or upper-middle class individuals" (Gifford & Nilsson, 2014, p. 149). In addition, the early adopters of smart home technologies are households that are highly educated and have a high income (Niamir et al., 2020; Nilsson et al., 2018). Hence, "if environmental actions save money in the long run, wealthier people can more easily afford the initial cost" (Gifford & Nilsson, 2014, p. 150).

In their study on 154 early adopting households, Nilsson et al. (2018) showed that even with the knowledge and feedback on energy consumption, there is a significant difference between household's energy consumption. According to Halkier, cited in Throne-Holst et al. (2008), "in daily life you will find a mixture of rational, intended behaviour and more routine practices, so that "a sharp distinction between reflexive and routinised consumption practices is impossible to sustain in empirical analysis" (p. 56). Households are encouraged to use less energy, but their energy consumption cannot simply be viewed as resource consumption (Shove, 2003). Electricity enables some services and conveniences: comfort in the form of heating or cooling and convenience through appliances and devices that help households manage their daily routines, such as freezers, microwaves and cars (Nikou, 2019a; Tirado Herrero et al., 2018). For households, reducing or shifting their energy load might affect their comfort or change their use of appliances in their daily life. Rommetveit et al. (2021) further developed the concept of comfort to the "comfort zone" in their study on users in the Norwegian smart electricity transition. Beyond heat, the comfort zone can also include service, for example, light, and the comfort zone is viewed as a limit. If the energy-saving measures threaten the comfort zone, they might be challenging to implement (Rommetveit et al., 2021). There can also be a conflict between an individual's values and attitudes; a person can report environmental concerns but still justify maintaining a certain consumption, for example, baths, because of comfort and well-being (Nilsson et al., 2018).

Socioeconomic characteristics and environmental attitudes are important, but with the development of the smart grid and the prosumer, technological interest and enjoyment is another essential factor to understand the behavioural change of the modern electricity household (Barjak et al., 2022; Schelly, 2014). Deciding to integrate innovations like smart home solutions, purchasing an electric vehicle, installing solar panels, or implementing energy efficiency measures entails behavioural changes that impact individuals' and households' daily lives and financial situations (Spandagos et al., 2022).

Technical complexities and social factors must be addressed for consumers to become prosumers in a smart grid. Therefore, understanding behaviour and behaviour change is necessary to implement the right interventions (Davis et al., 2015; Throne-Holst et al., 2008). Households have different motivations and needs to invest in smart home solutions. They can be driven by the following values and motivations: egoistic, driven, for example, by monetary incentives and bonuses; hedonistic, concerned with comfort and convenience; altruistic, focused on the benefit of others; and biospheric; concerned with ecology and nature (D'Ettorre et al., 2022; Kowalski et al., 2021). Incentives to change household behaviour should be set according to these values and motivations or in combination to increase the effect (Khanna et al., 2021).

3.3 Hypotheses

The literature shows that using smart home technology can lead to behaviour change, yet installing it broadly in society involves social risk and privacy concerns. Individual-level motivational factors are important for behaviour change, with socioeconomic characteristics, such as age, gender, education, and income, as determinants of environmentally friendly behaviour. Studies reveal that knowledge levels predict pro-environmental behaviour and early adopters of smart home technology are households that are highly educated and have high incomes. Moreover, literature suggests that behavioural change manifests in many ways, ranging from intended behaviour to more routine practices. In addition, electricity enables services and conveniences, and changing them can affect households' comfort. Given the insight from existing literature and the main objective of investigating the influence of participation in a pilot project on household behaviour along with identifying hindering and motivational factors for utilisation of household demand-side flexibility, the following hypothesis will be tested:

H1: Participation in the StrømFleks pilot resulted in greater changes in behaviour related to electricity consumption compared to a control group of non-participants.

H2: Various factors, including trust, cost considerations, concerns about privacy, technology familiarity, and environmental concerns, influence households’ willingness to provide demand-side flexibility.

4 Methodological Approach

This study examines households' behavioural changes and the utilisation of flexible resources as a demand-side response in a smart grid. As this is a future scenario, the StrømFleks pilot project is used as a case. The StrømFleks pilot project has only 150 participants, so the results of the study cannot be generalised. However, a case study can shed light on relevant issues and provide learning opportunities for energy supply chain managers and policymakers (O'Leary, 2021). Further, the study also investigates the behavioural changes related to participating in the pilot project in relation to electricity consumption and utilisation of flexible resources in the home. The design and strategy of this study is a comparative approach in which two groups of households are interviewed using a questionnaire: the households participating in the StrømFleks project and a control group of non-participating households. A questionnaire was chosen as the data collection method as it is a good tool in social science for gathering and analysing data to compare attitudes, behaviour and how the participants think about an issue (Stockemer, 2019). Primary data were collected by distributing a descriptive online questionnaire to the participants in StrømFleks and a control group. In addition, an online survey was chosen as it could be administered to a larger number of participants, it allowed the respondents to answer the questions anonymously, and it was more efficient to administer and analyse within the timeframe of the study (O'Leary, 2021).

4.1 Questionnaire design

The questionnaire was developed through a literature review on smart grids, flexibility, prosumers, aggregators, co-creation, and behavioural change. Five people read the questionnaire and commented during the development of the questions, including the project manager of StrømFleks and the portfolio manager of R&D at Lede. Based on their review, the questionnaire was developed in Nettskjema, a secure web-based survey tool used in academic research and approved by USN (Nettskjema, n.d.). To provide measurable variables, the questionnaire was developed with closed-ended questions (Silverman, 2020). It comprises a mix of single-answer, multiple-choice, categorical, rank-order, and matrix table questions (Stockemer, 2019). Motivational or behavioural questions are measured using a Likert scale with five to six choices so the data can be ordered or ranked to measure the respondent's attitudes and opinions (Stockemer, 2019). Once the draft questionnaire had been finalised, the link to the online questionnaire with self—disclosure was distributed to six test households. The test revealed that some terms were too topic-specific or technical and were revised. In addition, one participant pointed out that they did not find the right category for the household income level as the lowest income started at 600.000. The first category of income level was revised to below 600.000. Based on the average time the test persons used to complete the questionnaire, the respondents to the questionnaire could be informed that it would take 10-15 minutes to complete.

The questionnaire was developed and distributed in Norwegian, as the participants in this study are all inhabitants of the region of Porsgrunn, Norway. In the process of translating the questionnaire from Norwegian to English, "ChatGPT" (2024) was used, and the researcher proofread the translated version, which is included in the Appendix of this paper (see Appendix 3).

4.2 Ethical considerations

The study has ethical obligations towards the interest and welfare of the participants and stakeholders of this research (O'Leary, 2021). In the introductory statement, the study was introduced, the purpose of the research stated, why they were selected, that their participation is voluntary, how the data they provide will be stored and that they have the right to withdraw at a later stage (see Appendix 2). The questionnaire was distributed to the participants by email; they gave their informed consent to participate by submitting their replies. Consideration has been taken to ensure that power dynamics related to gender, age, education, and ethnicity do not influence the questionnaire, with careful attention paid to the language to prevent alienating participants.

The questionnaire was anonymised as it was a self-administrated online questionnaire using Nettskjema. However, the survey collected multiple data that, if combined, the set of information could be linked to a specific person, and therefore, the research was submitted to Sikt, the Norwegian Agency for Shared Services in Education and Research, for Data Protection Services to check that the research complied with the data protection legislation (Sikt, n.d.). This study got approval from Sikt, and the approval ensures that the processing of personal data in this project fully complies with privacy regulations, providing reassurance of the study's ethical integrity. Data storage coincides with USN’s established procedures and infrastructure for research data.

4.3 Data collection

Lede distributed the questionnaire via email to the original 150 participating households, ensuring that even those who opted out when the project was extended had the opportunity to respond. The questionnaire information letter is included in the Appendix (see Appendix 1). In the StrømFleks group, 33 participants completed the questionnaire, a response rate of 22 per cent. The control group of non-participants was formed by posting information about the questionnaire and the link to Nettskjema in the public Facebook group “Porsgrunn i dag” (Porsgrunn today) with 15,400 members (Porsgrunn i dag, n.d.). The response rate in the control group was 0.2 per cent. 33 households responded to the questionnaire, making it comparable to the participating group in the StrømFleks project. “Porsgrunn I dag” was selected as Lede had previously used this site to recruit participants for an interview for the ForTa project (Vindegg et al., 2023). The information letter to the control group is included in the Appendix (see Appendix 2). Information from the participants was collected at a specific moment in time, and it was, therefore, cross-sectional (Stockemer, 2019). As the StrømFleks project only comprised 150 participants, the maximum number of responses was limited to 150 in Nettskjema for both groups. The two questionnaires were identical and were distributed at the same time with the same deadline, from the 26th of February until the 6th of March 2024. Lede sent one reminder to the StrømFleks participants, and two reminders about the questionnaire were posted on the original post in the Facebook group.

Some potential risks have been identified for this study. The common method bias will be addressed by guaranteeing anonymity to the questionnaire participants (Kock et al., 2021). To reduce the risk of a high non-response, two incentives were introduced. One was the possibility of receiving a summary of the findings at the completion of the study. The second was the possibility of entering a drawing for a gift card worth 500 NOK.

4.4 Data analysis

The questionnaire was divided into the following parts. One part contains questions related to the socio-economic characteristics of age, gender, education level, income level and ownership of the home. The second part consists of questions related to electricity usage, changes in the household's daily routines to limit their electricity consumption, change of electricity supplier, the influence of the new grid tariff, acceptance of new technologies and questions related to the utilisation of flexibility. Motivational aspects were addressed in the third section using a 5-point Likert Scale, covering attitudes towards smart home technology, factors influencing willingness to enter an agreement of control of flexible resources and which actor would be allowed control (see Appendix 3). The fourth and last part is solely for the participants in the StrømFleks project and relates to their motivation for participation and satisfaction with the project.

The data will be analysed using Stata software, and econometric models will be used to analyse the outcome variables in relation to socio-economic characteristics. A wide range of methods are used to identify clusters of green customers, motivation, and usage, e.g. ANOVA, cluster analysis, logit and probit analysis, ordered probit and ordered logit models for the Likert scale variables and non-response analysis to investigate the determinants of this type of bias. Due to the lack of generalisability, a purely quantitative research method is used.

4.5 Empirical model

The following section of the empirical approach will be divided to accommodate the two research questions. First, the empirical models for RQ 1 will be explained. This study will examine the behaviour changes of the participants in the StrømFleks pilot project, analysing the direct impact related to knowledge of electricity consumption and reduction in kilowatt-hour (kWh) by applying the difference-in-difference (DID) approach. The DID will be applied in combination with a probit model to determine if there are any differences in relation to socio-economic characteristics between the StrømFleks participants and a control group of non-participants. Further, behaviour changes related to shifting flexible resources to times with lower grid demand will be examined using cross-tabulation tables and chi-square tests to estimate the project's impact on behavioural changes compared to the control group. Secondly, the empirical models for RQ2 will be described. The factors that motivate or hinder households in providing demand-side flexibility will be examined using cross-tabulations and the Pearson chi-square test (Stockemer, 2019).

4.5.1 Difference-in-differences and probit model of behaviour change

To evaluate the impact of participation in StrømFleks on the household's electricity consumption, two outcome variables are considered: knowledge of the electricity consumption and the amount of electricity consumed in kWh. The difference-in-differences (DID) approach estimates the treatment effects of StrømFleks participation on outcome variables. The approach is described in detail in Angrist and Pischke (2009) and Card and Krueger (1994). The DID approach requires two groups of units i, including a treated group to which the treatment is delivered (treated= 1), which is the participation in StrømFleks and a control group of non-participating households in the same municipality to which the treatment is not delivered (treated= 0) (Villa, 2016). The DID approach compares the changes in the likelihood of knowing the electricity consumption in the treated group with the control group. The definition of the DID treatment effect is based on the existence of at least two time periods, one baseline (t = 0) and one follow-up (t = 1) (Card & Krueger, 1994; Pischke & Angrist, 2009). In this study, the baseline period is 2019, and the follow-up period is 2023. The DID approach is combined with a probit model. The specification can be written as:

$$DKwh_{it}^{*} = \beta_0 + \beta_1 \text{period}_i + \beta_2 \text{treated}_i + \beta_3 \text{period}_i \times \text{treated}_i + \mathrm{X}_i \alpha + \varepsilon_{it,}$$

Where $DKwh_{it}^{*}$ denotes the probability of knowing the electricity consumption and the relationship between the observed 0/1 variable and the likelihood of knowing the electricity consumption is defined as:

$$DKwh_{it} = \begin{cases} 1 & DKwh_{it}^{*} > 0 \\ 0 & otherwise \end{cases}.$$

The individual respondent is i=1,….,66 and period =2019 and 2023. β_0 is the constant and ε_{it} is the error term. The vector X includes observable covariates, such as socioeconomic characteristics, as described below. The parameter, β_3 measure the treatment effect, which measures the difference between the treated and the control groups at the baseline (Card & Krueger, 1994). A positive and significant sign of β_3 means that participation in StrømFleks has increased knowledge of households' electricity consumption. The period dummy controls for all common time-varying factors, such as energy price increases, and controls for the fact that knowledge of current electricity consumption is generally higher for the current period than four years ago. The DID treatment effects can be estimated with repeated cross-sections or panel data (Villa, 2016). The information in this study is based on one questionnaire with retrospective data for 2019 and 2023. This means that the sample is almost balanced.

A probit model will be used for the regression as knowledge of kWh is a binary dependent variable (Wooldridge, 2020, Chapter 17). This is a categorical variable that can take only two values: Respondents know their electricity consumption, measured in kWh, or they do not know it (Wooldridge, 2020). The determinants of the likelihood of knowing the electricity consumption are modelled based on the following characteristics: The dependent variable is the binary outcome of knowing the electricity consumption in 2019 and 2023. It is derived from the response to the following questions: Question 2: “Do you know, without checking, how many kWh your household used in 2019?” and Question 3: “Do you know, without checking, how many kWh your household used in 2023?” (see Appendix 3). If the household knew their electricity consumption in kWh, they provided their estimated number; otherwise, they wrote zero (O) in the reply. The characteristics representing the independent variables in the probit models are the participation in StrømFleks, age groups (35 to 44 years, 45 to 54 years, 55 to 64 years, 65 years and older), the education level of a master's degree/Ph.D., and gender (women). The determinants of the likelihood of knowing the electricity consumption (dkWh) are specified as follows (Wooldridge, 2020):

$$Pr(dkwh = 1) = \Phi(\beta_0 + \beta_1\ StrømFleks + \beta_2\ year2023 + \beta_3\ age35to44 + \beta_4\ age45to54 + \beta_5\ age55to64 + \beta_6\ age65andolder + \beta_7\ mastergrad/Ph.D. + \beta_8\ woman),$$

4.5.2 Cross-tabulation and chi-square tests of behaviour changes

Before the results of the probit model are presented, the changes in behaviour in connection with the shifting of flexible resources to times with lower grid demand are examined using cross-tabulation tables and chi-square tests. All tables and tests are compared with the control group. Cross-tabulation tables are used because the dependent and the independent variables are binary (Stockemer, 2019). This section aims to show whether participation in StrømFleks has led to a higher chance for behavioural change related to flexibility than in the control group by investigating the relationship between several categorical variables (Stockemer, 2019).

Behaviour changes related to shifting flexible resources to times with lower grid demand are measured in response to the following questions: Question 4: “Has the household changed daily routines to limit electricity consumption?” (see Appendix 3). The replies were recorded as yes and no. Question 5: “If the household changed daily routines to limit electricity consumption, which routines have been changed?” (see Appendix 3). This question only appeared to the respondents who answered “yes” in Question 4. The question lists different daily routines, but in relation to flexibility, only the following two are relevant: “Moved energy-intensive tasks such as laundry and dishwasher to times with lower electricity prices” and “Moved electric car charging to times with lower electricity prices”. Responses were documented as “Have done this” and “Have not done this”. Question 7: “Has the new grid tariff model influenced how electricity is used in the household?” (see Appendix 3). Entries were noted as “Yes, we have set limitations in the app for smart energy management”, “Yes, we have evened out electricity consumption to limit capacity charges”, “No, use electricity in the same way as before the new grid tariff model”, “Not aware of the new grid tariff model” and “Do not know”. The answers “Yes, we have set limitations in the app for smart energy management” and “Yes, we have evened out electricity consumption to limit capacity charges” were merged and made up yes. The other three replies make up no. Lastly, the study would like to determine whether the households own an EV and use a smart charger by employing cross-tabulation and chi-square tests to Question 11 (see Appendix 3), “Does the household own an electric car and use smart charging?”. The answers were registered as “Yes,” “Owns an electric vehicle but does not use smart charging,” and “No.”

Cross-tabulations table and chi-square tests will be applied to investigate the patterns across the different variables between the participation in StrømFleks on behavioural changes and the control group. The formula for the cross-tabulation is specified as follows (Stockemer, 2019):

$$\frac{\text{Row total x Column total}}{\text{Table total}}$$

The formula for the chi-square test is specified as follows (Stockemer, 2019):

$$x2 = \frac{(Observed - Expected)2}{Expected}$$

4.5.3 Cross-tabulation of factors that motivate or hinder the utilisation of demand-side flexibility

The following three questions will be cross-tabulated to examine factors that motivate or hinder households in providing demand-side flexibility. First, question 13 in the questionnaire (see Appendix 3), “Is the household willing to enter into an agreement with the grid owner/electricity supplier/ third party to manage electricity usage in the household, provided it does not affect the comfort?”. The answers were recorded as “Yes”, “No”, and “Don’t know”. For the respondents who answered that they were willing to enter into an agreement they got the follow-up question, question 15: “If the household were to let someone else control the flexibility, who should it have been?”. To this question, the answer possibilities were “The grid company, Lede”, “The electricity supplier”, “A new actor”, “A governmental institution”, and “Don’t know”. The third and last questions were possible to answer for all the respondents. Question 17 (see Appendix 3), “Which factors will influence the decision to enter an agreement on controlling flexible resources in the household?”. The households were asked to rate the following factors “Nature and environment”, “Social”, “Economic”, “Understanding of technology”, “Privacy”, “Reputation of the grid owner/electricity supplier/third party”, and “Personal social image/reputation”. The households' attitudes were measured with the following five pre-coded choices employed in a Likert scale (Stockemer, 2019): “Very important”, Important”, “Neutral”, Less important” and “Not important”.

5 Results

Initially, descriptive statistics with the sample profile of the survey respondents are presented. Subsequently, the results are reported following the steps of the empirical analyses, divided according to the two research questions and methods. The analysis proceeds to assess the impact of the pilot project on behavioural changes. Finally, factors motivating or hindering the adoption of flexibility are examined.

5.1 Descriptive statistics

For an initial overview of the two groups of respondents, the descriptive statistics are presented in Table 5-1, Sample profile of respondents. The descriptive statistics include demographic information, including gender, age, education, income, and ownership of their home. In addition, the household's technology interest, usage of smart home technology and whether the household owns an EV are displayed as part of the respondents' sample profile. The sample size for the two groups of respondents to the survey is 33 for the participants in StrømFleks and 33 respondents in the control group of non-participants. The two groups, StrømFleks and the control group, are presented in two columns, with the frequency and percentage for each variable presented in its affiliated group.

Table 5-1 Sample profile of respondents (N = 66).

Item	Variable	Total (N = 33) StrømFleks participants	Total (N = 33) Control Group
Gender			
	Men	28 (84.8%)	16 (48.5%)
	Women	5 (15.2%)	17 (51.5%)
Age			
	25-34 years	5 (15.2%)	4 (12.1%)
	35-44 years	8 (24.2%)	7 (21.2%)
	45-54 years	6 (18.2%)	14 (42.4%)
	55-64 years	6 (18.2%)	5 (15.2%)
	65 years and above	8 (24.2%)	3 (9.1%)
Education			
	Primary school	1 (3.1%)	1 (3%)
	High school	6 (18.8%)	10 (30.3%)
	Bachelor	11 (34.4%)	9 (27.3%)
	Master's degree/Ph.D.	14 (43.7%)	13 (39.4%)
Income (NOK)			
	< 600.000	2 (6.1%)	3 (9.1%)
	600.000-1.000.000	10 (30.3%)	7 (21.2%)
	1.000.000-1.400.000	9 (27.3%)	9 (27.3%)
	1.400.000-2.000.000	9 (27.3%	9 (27.3%)
	> 2.000.000	1 (3%)	4 (12.1%)
	Prefer not to say	2 (6.1%)	1 (3%)
Ownership of home			

	Owner	32 (97%)	31 (93.9%)
	Renter	1 (3%)	0
	Other	0	2 (6.1%)
Technology interest			
	Early adopter	18 (54.5%)	10 (30.3%)
	Majority	11 (33.3%)	16 (48.5%)
	Late adopter	4 (12.1%)	7 (21.2%)
The household uses smart home technology			
	Yes	28 (84.8%)	12 (36.4%)
	No	4 (12,1%)	19 (57.6%)
	Do not know	1 (3%)	2(6.1%)
Owns an electric vehicle			
	Yes	23 (69.7%)	19 (57.6%)
	No	10 (30.3%)	14 (43.7%)

Note: Percentages may not add up to 100 due to missing values.

Source: own survey.

The distribution of socio-demographics and sample profile shows that the sample does not correspond with the socio-demographics of the population in Norway. Among the StrømFleks participants, gender is not sufficiently balanced as men constitute 84.8 per cent of the sample, while in Norway, 50.4 per cent of the population are men (*07459*, n.d.). In the control group, the gender participation was more evenly distributed, with 51.5 per cent men and 48.5 per cent women. The largest age group among the StrømFleks participants were 35-44 years, at 24.2 per cent, while the largest age group in the control group was 45-54 years, with 42.4 per cent. Concerning education, the dominant group was the highest education level, master's degree/Ph.D., for both groups, with 43.7 per cent in StrømFleks and 39.4 per cent in the control group. Bachelor-level education was the second most dominant group, with 34.4 per cent of the StrømFleks participants achieving this level of education, and 27.3 per cent of the control group have a bachelor's education. In the Norwegian population, 33 per cent have higher education, bachelor-level or above, but in the two sample groups, between 66 to 77 per cent have attended a higher level of education (*Educational Attainment of the Population*, n.d.). The largest income group was 600.000 – 1.000.000 NOK in the StrømFleks with 30.3 %, followed by 1.000.000 - 1.400.000 NOK and 1.400.000 – 2.000.000 NOK with 27.3 per cent for both groups, respectively. The yearly median income in Norway is 608.000 NOK per year (*Hva er vanlig lønn i Norge?*, n.d.).

In both groups, the respondents mainly own their homes, with 97 per cent owners among StrømFleks and 93.9 per cent owners in the control group, while 65 per cent of the Norwegian population own the house they live in (*14070*, n.d.) StrømFleks has a more significant proportion of respondents that define themselves as early adopters of technology at 54.5 per cent. In contrast, mainstream adopters, at 48.5 per cent, are the largest group among the control group. Among the respondents in StrømFleks, 84.8 per cent use smart home technology, while 36.4 per cent of the control group use it. Within the participants of StrømFleks, 69.7 per cent own an EV, whereas 57.6 per cent of the control group own one. At the end of 2023, 23.9 per cent of the registered private cars in Norway were an electric vehicle (*Registered Vehicles*, n.d.).

Although the respondents do not perfectly correspond with the socio-demographics of the population, except for gender representation, the two groups exhibit similarities and are well-suited for a comparative approach.

5.2 Knowledge of electricity consumption

The summary statistics for the mean knowledge of energy consumption and the summary statistics of the mean consumed electricity kWh for the years 2019, and 2023 for the two groups will be presented, respectively. Figure 5-1 reports households' self-perceived likelihood of knowing their energy consumption. The data is grouped by year, 2019 and 2023, and by group, StrømFleks and the control group. This provides insights into the group's mean knowledge of their electricity consumption in those two years. The figure shows that 59 per cent of the participants in StrømFleks know their electricity consumption.

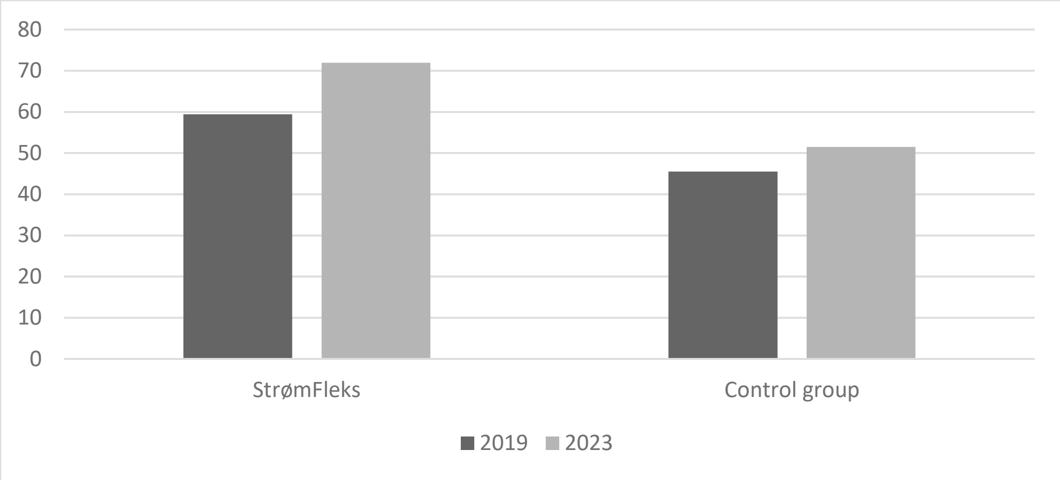

Figure 5-1 The likelihood of the household knowing their electricity consumption (N = 66).

Note: knowledge of kWh is reported in per cent.

Source: own survey.

in 2019, and it increased to 72 per cent in 2023. In the control group, 46 per cent of respondents knew their energy consumption in 2019, and their knowledge increased to 52 per cent in 2023.

In Table 5–2, the respondents' mean reported electricity consumption in kWh is presented for each year and group in the sample. The respondents who reported their consumption only in 2023 and not 2019 are excluded from the mean as these outliers would affect the mean. The participants in StrømFleks reported lower kWh in 2019 than the control group, 20.684 kWh and 23.521 kWh, respectively. In 2023, the participants in StrømFleks reported a consumption of 18.904 kWh, a reduction of 8.6 per cent from 2019. The control group reported higher consumption than StrømFleks in 2023, with 21.643 kWh, which was an 8 per cent reduction from 2019.

Table 5-2 Reported electricity consumption in kWh in 2019 and 2023 (N = 66).

	StrømFleks	Control group
2019	20684	23521
2023	18904	21643
Reduction from 2019 to 2023	1780 (8.6%)	1878 (8%)

Source: own survey.

5.3 Difference-in-differences estimation of the effect of StrømFleks participation on electrical consumption

Figure 5–2 shows the effect of the StrømFleks project treatment on electrical consumption controlled towards the control group. The difference-in-differences estimate, with a p-value of 0.747, indicates that the observed effect is not statistically significant.

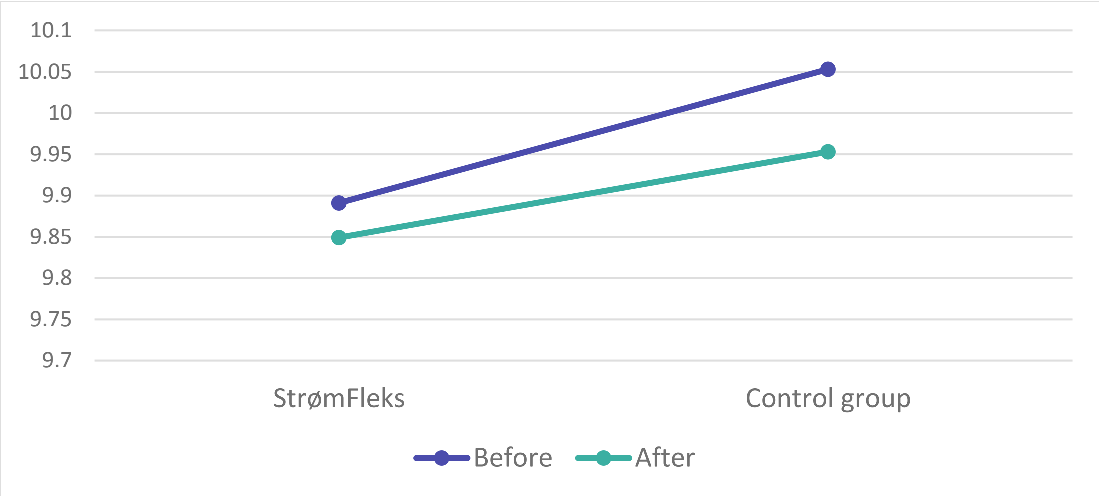

Figure 5-2 Difference-in-differences estimation of the effect of the StrømFleks project on electrical consumption (N = 65).

Note: Diff-in-Diff estimate: 0.057. P-value: 0.747. The left axis displays the logarithm of electricity consumption, which is used to account for the distribution of consumption and interpretation.

For the difference-in-differences estimates, see Table A4–3 in the appendix.

Source: own survey.

5.4 Probit analysis of knowledge of electricity consumption in relation to socio-economic characteristics

Table 5 -2 shows the Descriptive statistics of the likelihood of knowing electricity consumption among the participants in StrømFleks (N = 130). The number of observations is 130 as the knowledge of electricity consumption is recorded for the years 2019 and 2023, respectively. Different variables were chosen to investigate if socio-economic characteristics influence the likelihood of the household's knowledge of their electricity consumption. The variables include whether the participants were part of the project, age categories, educational level (Master's degree/Ph.D.) and gender (Woman).

Table 5-2 Descriptive statistics of the likelihood of knowing electricity consumption (N = 130).

	Observations	Mean	Std.dev.	Min.	Max.
StrømFleks	130	0.492	49.7 %	0	1
StrømFleks x year 2023	130	0.500	50.2 %	0	1
35 to 44 years	130	0.231	42.3 %	0	1
45 to 54 years	130	0.308	46.3 %	0	1
55 to 64 years	130	0.169	37.6 %	0	1
65 years and older	130	0.154	36.2 %	0	1
Master's degree/Ph.D.	130	0.415	49.5 %	0	1
Woman	130	0.338	47.5 %	0	1

Note: The number of observations is 130 as the knowledge of electricity consumption is recorded for the years 2019 and 2023, respectively, with 65 observations per year. Source: Own survey.

The descriptive statistics in Table 5-3 illustrate the likelihood of StrømFleks participants knowing their electricity consumption in 2023 across various variables, including participation in StrømFleks, year, age categories, education level (Master's degree/Ph.D.) and gender (Woman).

Table 5-3 Descriptive statistics of the participant's likelihood of knowing their electricity consumption in 2023 (N = 63).

	Observations	Mean	Std. Dev.	Min	Max
Knowledge of kWh	63	9.916	35.4 %	9.21034	10.645
Participants	63	0.556	50.1 %	0	1
Year 2023	63	0.556	50.1 %	0	1
35 to 44 years	63	0.222	41.9 %	0	1
45 to 54 years	63	0.365	48.5 %	0	1
55 to 64 years	63	0.190	39.6 %	0	1
65 years and older	63	0.159	36.8 %	0	1
Master's degree/Ph.D.	63	0.381	49.0 %	0	1
Woman	63	0.143	35.3 %	0	1

Note: Own Survey.

The probit estimates (Table 5–4) of the determinants of the likelihood of knowing the electricity consumption reveal a small increase in the likelihood of knowing the electricity consumption in 2023 as the coefficient is 0.184. The treatment effect of 0.09 indicates a nine per cent increase in knowledge compared to the baseline between 2019 and 2023 for both groups. However, the coefficient for the year 2023 has a p-value greater than 0.05, indicating that the increase in knowledge is not significant for either of the groups. None of the age categories are statistically significant. Further, the estimate reveals that knowledge about electricity consumption is 10 per cent lower among households with higher education, a master's degree or higher, with a negative treatment effect of -0.10. Still, again, the marginal effect is not significant. The only significant variable is gender, as women have a 39 per cent points lower probability of knowing their households' electricity consumption. The treatment effect for women is -0.39 and is statistically significant at the 1 per cent level as the coefficient is -1.200 and a p-value of -4.25.

Table 5-4 Probit estimates of the determinants of the likelihood of knowing the electricity consumption (N = 130).

	Coeff.		z- stat	dy/dx		z-stat
StrømFleks	-0.010		-0.03	0.031		0.35
Year 2023	0.184		0.55	0.094		1.21
StrømFleks X year 2023	0.213		0.45	0.065		0.53
35 to 44 years	-0.202		-0.48	-0.066		-0.48
45 to 54 years	0.026		0.06	0.008		0.06
55 to 64 years	0.090		0.19	0.029		0.19
65 years and older	-0.164		-0.38	-0.054		-0.38
Master's degree/Ph.d.	-0.294		-1.21	-0.096		-1.23
Women	-1.200	***	-4.25	-0.391	***	-5.53
Constant	0.625		1.31			
Number of observations	130					
Pseudo R2	0.158					

Note: Asterisks ***, ** and * denote statistical significance at the 1, 5 and 10 per cent level. The dataset contains 130 observations, as the respondents' answers are recorded according to the years 2019 and 2023, and the probit regression investigates both years. The probit estimates and marginal effects are in Tables A4–1 and A4–2, respectively, in the appendix.

Source: own survey.

5.5 Cross-tabulation of behaviour changes related to flexibility

Figure 5-3 presents the results of the cross-tabulation and chi-square tests of "The household has changed routines to limit electricity consumption", "New grid tariff has influenced how electricity is used in the household", "Moved energy-intensive tasks such as laundry and dishwasher to times with lower electricity prices" and "Moved electric car charging to times with lower electricity prices" for the participants in StrømFleks and the control group. Change in daily routines, with a chi-square value of 3.62 and a corresponding p-value of 0.057, is not statistically significant, while the mean comparison in the cross-tabulation indicates that the proportion of households changing their daily routines is higher in StrømFleks (81.8 per cent) than the control group (60.6 per cent). In relation to the influence of the new grid tariff, the chi-square value is 4.93, and the corresponding significant level of 0.026 suggests statistical significance. In addition, the mean comparison shows that participants in StrømFleks (66.7 per cent) have adopted more changes in relation to the new tariff than the control group (39.4 per cent). The mean comparison for whether the respondents have moved energy-demanding tasks like dish- and clothes-washing to times with lower electricity prices: 54.5 per cent of the participants in StrømFleks have done this, while the mean for the control groups is 39.4 per cent. However, the results lack statistical significance (Pearson chi2(1) = 0.09 and p-value 0.762). When it comes to the behaviour of charging the EV, 42.4 per cent of the StrømFleks have moved the charging to a time with lower electricity prices, while 30.3 per cent of the control group have done this. This result is not statistically significant (Pearson chi2(1) = 0.51 and p-value of 0.474).

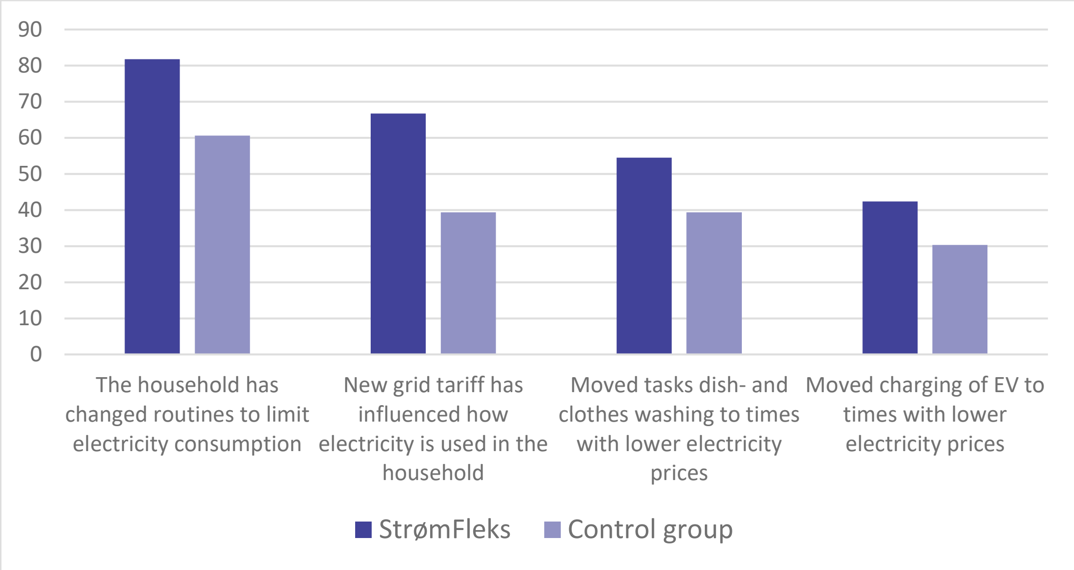

Figure 5–3 Behavioural changes related to flexibility (N = 66).

Note: Figured in per cent. Household routines: Pearson chi2(1) = 3.62 and p-value = 0.057. New grid tariff: Pearson chi2(1) = 4.93 and p-value = 0.026. Moved dish- and clothes washing: Pearson chi2(1) = 0.09 and p-value of 0.762. Moved charging of EV: Pearson chi2(1) = 0.51 and p-value 0.474.

See the cross-tabulation and chi-square test in Tables A4–4, A4-5, A4-6, and A4-7.

Source: Own survey.

As illustrated in Figure 5-4, more than half of the respondents in both groups who own an EV, 36.4 per cent of the respondents in each group, do not use a smart charger. Among the respondents who use a smart charger, the participants in StrømFleks (33.3 per cent) are more represented than the control group (21.2 per cent).

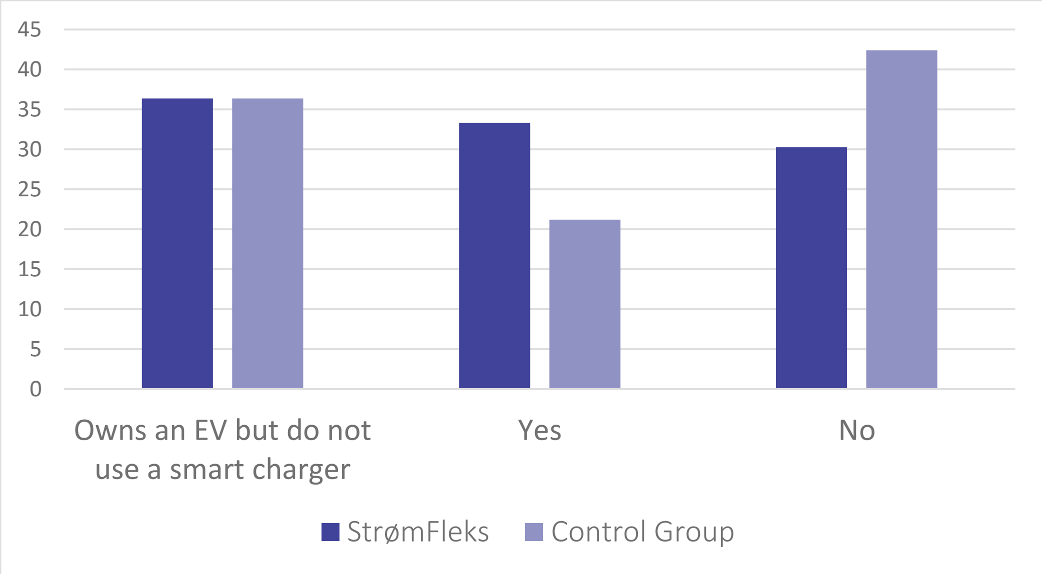

Figure 5-4 Does the household own an electric vehicle and use a smart charger? (N = 66).

Note: Figured in per cent. Pearson chi2(2) = 1.56 and p-value 0.459. For the full cross-tabulation and chi-square test, see Appendix Table A4-7.
Source: Own survey.

The results of the chi-square test (Pearson chi2(2) = 1.56 and p-value 0.459) revealed that there is no significant association between owning an EV and using a smart charger.

5.6 Cross-tabulation of factors that motivate or hinder the utilisation of demand-side flexibility

In this section, the study will focus on the respondents' views on different aspects of their attitudes towards demand-side flexibility in the future. Figure 5-5 shows the respondents' willingness to enter into an agreement with a grid owner/electricity supplier/ third party to manage electricity usage in the household, provided it does not affect comfort.

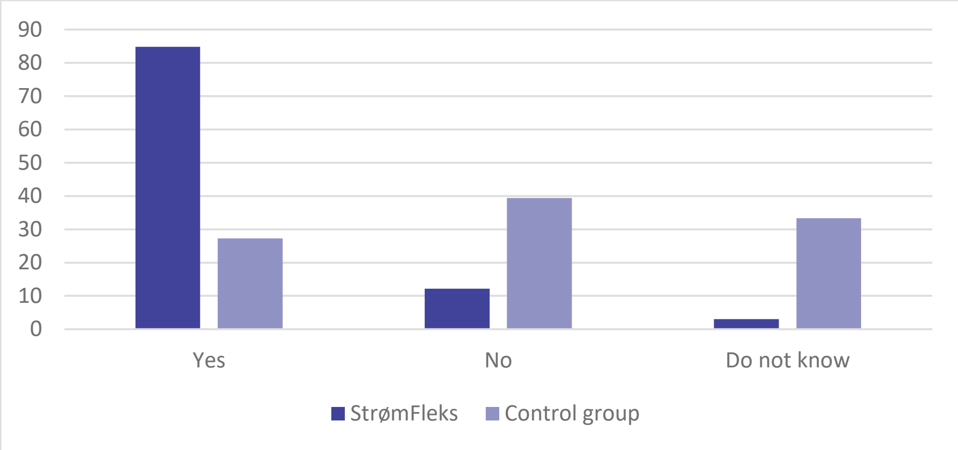

Figure 5-5 Willingness to enter into an agreement of control of flexible resources (N=66).

Note: Figured in per cent. Pearson chi2(2) = 22.85 and p-value = 0.000. See full cross-tabulation and chi-square test in Table A4-9.
Source: Own survey.

The respondents who participated in the StrømFleks pilot project (85 per cent) are more willing to enter into an agreement than the control group (27 per cent). In the control group, most respondents answered that they are not willing to (39 per cent) or are uncertain (33 per cent) if they are willing to enter into an agreement with external control of electricity usage. The results are statistically significant with a chi-square test of 22.85 and a p-value of 0.000, which is significant at the 1 per cent level.

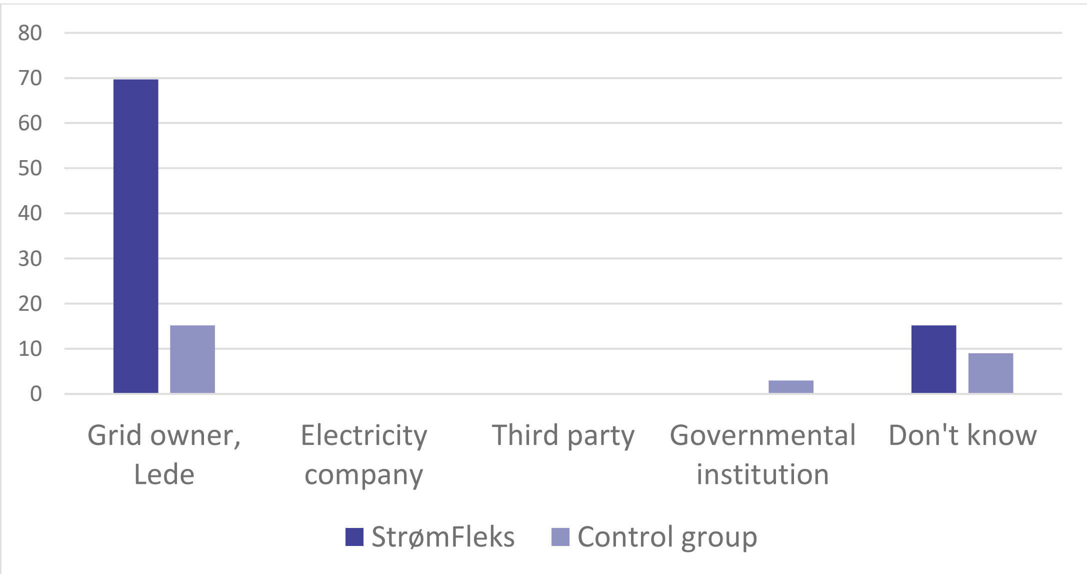

Figure 5-6 Which actor shall control the flexible resources?

Note: Figured in per cent based on the total number of respondents (N=66). This question was only answered by those who were willing to enter into an agreement for external control of flexible resources (N = 37). See full cross-tabulation in Table A4-10.
Source: Own survey.

In Figure 5-6, it is reported which actor the respondents in the two groups would like to control the flexible resources if they were to enter into an agreement with external control. The question was a filter question, and therefore, only the respondents who answered yes to the previous question (Figure 5-4) were able to answer it, 28 of the StrømFleks participants and nine from the control group. The majority of the respondents from the StrømFleks group (69.7 per cent) prefer the grid owner, Lede, to control their flexible resources. None of the respondents preferred the electricity company or a third party. Some respondents from each group, 15.2 per cent from StrømFleks and 9 per cent from the control group, were uncertain about who they would allow to control the flexible resources. The study couldn't perform a chi-square test for this question due to a limitation of the test, which requires a minimum cell count of 5 for all cells to be maintained (Stockemer, 2019).

Table 5-4 Cross-tabulation of the factors that motivate or hinder the utilisation of demand-side flexibility (N = 65).

	Very important	Important	Neutral	Less important	Of no importance
Economic	32	24	7	1	1
Privacy	25	16	13	7	4
The reputation of the grid owner/electricity supplier/third-party	17	18	20	5	5
Societal	9	24	18	11	3
Nature and environment	8	24	17	9	7
Technology understanding	7	26	25	5	2
Own social image	3	6	29	10	17

Note: N = 65. The responses from the StrømFleks participants and the control group are combined in the table as the results were similar. See the independent cross-tabulations for StrømFleks and the control group in Tables A4-11 and A4-12.
Source: Own survey.

Table 5-4 reports the factors that motivate or hinder the use of demand-side flexibility. Most of the respondents find the economic factor to be the most important factor. After the economic factor, privacy and the reputation of the grid owner/electricity supplier/third party are the second and third most important factors, respectively. Then, there are three factors the respondents value equally important: societal, nature and environment, and technology understanding, as they rate it important but not very important. Their own social image is the factor the respondents found the least influential factor in their willingness to enter into an agreement of control of flexible resources in the household.

6 Discussion

First, the study investigates the findings from the analysis of research question one: “Does participation in a pilot project managing flexible resources change household behaviour?” This examination initially focuses on the influence of the project on knowledge of electricity consumption, followed by an assessment of its influence on behaviour change related to flexibility. Secondly, the study explores the results of research question two: “What factors motivate or hinder households in providing demand-side flexibility?”. Lastly, these findings are examined in the context of stakeholder implications for the integration of demand-side flexibility into the market.

6.1 Behavioural change in household electricity consumption

Participation in the StrømFleks pilot project was an incentive-based demand response program as the participants received smart home technology that allowed Lede direct control over the household's load management (D’Ettorre et al., 2022). The literature suggests that smart home technology can enhance change by providing households with feedback on their electricity consumption (Sovacool, 2021). However, the study did not find that using smart home technology increased the participants' knowledge of their electricity consumption in kWh compared to the control group.

Evidence based on descriptive statistics and the probit model shows that a remarkably large number of households in both groups did not know their electricity consumption. One factor contributing to this trend may be the historically low cost of electricity in Norway until 2021 and 2022, when prices per kWh saw a dramatic increase, nearly doubling initially and then tripling compared to 2019 (see Figure 2-2). Descriptive statistics (see Figure 5-1) indicate an increase in knowledge of household consumption between 2019 and 2023. However, the probit estimates (see Table 5-3) show that this is not significant at conventional significance levels.

The households participating in StrømFleks had more knowledge about their electricity consumption (see Table 5-2) than the control group in 2019 and 2023. One contributing aspect could be that participants in the pilot project were potentially more aware of their energy usage and its effect before the project started, thereby motivating their participation. Looking at the reported electricity consumption in kWh in Table 5 -2, the participants in StrømFleks used about 2700 kWh less than the control group in 2019 and 2023. Both groups reported about 8 per cent reduction in kWh from 2019 to 2023. The difference-in-differences estimates (see Figure 5-2) showed no statistically significant impact of participating in the StrømFleks project on electricity consumption.

The probit estimates (see Table 5-3) of the determinants of the likelihood of knowing the electricity consumption in relation to socio-economic characteristics showed that age and education were insignificant. Gender was the only significant characteristic, as women were 39 percentage points less likely than men to know their consumption. However, with only five female respondents among the StrømFleks participants, the results should be interpreted cautiously; thus, these results cannot be generalised.

Based on these results, H1, "Participation in the StrømFleks pilot project resulted in greater changes in behaviour related to electricity consumption compared to a control group of not participants", is rejected as it does not appear that the project participation had a direct impact on the participants' knowledge of their electricity consumption. The sharp rise in electricity prices during the pilot project period and the introduction of a new grid tariff model in July 2022 can have affected the impact of the pilot project in comparison with the control group in terms of knowledge and reduction in electricity consumption.

6.2 Behavioural change related to household demand-side flexibility

This study hypothesized that participation in the StrømFleks project would result in more change in behaviour related to electricity consumption compared to a control group of non-participants. While H1 was rejected regarding its impact on electricity consumption, the study found some support for the hypotheses on behavioural change related to demand-side flexibility.

Households participating in StrømFleks have changed their routines to limit their electricity consumption more (81.8 per cent) than the control group (60.6 per cent). The chi-square value indicated a marginal significance, indicating a trend that a higher proportion of participant households altered their daily habits, but the results was not statistically significant.

In terms of the new grid tariff, project participants exhibit a higher adoption rate (66.7 per cent) in adjusting household electricity usage compared to the control group

(39.4 per cent). Statistical analysis reveals this difference to be significant, indicating a notable disparity in the group's responses to the new tariff. The new grid tariff was introduced to encourage electricity consumers to level their consumption to avoid peaks. The new fee is differentiated based on the capacity the consumers need in the electricity grid (NVE, n.d.). Households that use smart home technology can set capacity limits in their app system according to the grid tariff and follow their real-time energy consumption. Utilising the flexible resources in the households by shifting them to times with less demand levels out the capacity needed in the grid. Participants in StrømFleks all have smart home technology, which can increase their awareness and the possibility of adjusting according to the new grid tariff.

A higher proportion of the participants in StrømFleks (54.5 per cent) reported moving energy-demanding tasks like running the dishwasher or washing clothes to times with lower electricity prices. Times with the lowest prices in 24 hours typically have the most capacity in the grid (*The Power Market*, n.d.). With less knowledge and awareness, it is more difficult for households to shift their behaviour, which might explain why only 39.4 per cent of the control group have moved energy-demanding tasks. In addition, by participating in a pilot project to utilise flexible resources, the participants will have received more information regarding flexible resources in their homes and increased their knowledge on this topic compared to the non-participants. However, the analysis did not find the difference between the two groups statistically significant.

Moving EV charging to times with lower electricity prices was performed the least by both groups in the study. Although a higher proportion of households participating in StrømFleks (42.4 per cent) had moved EV charging compared to the control group (30.3 per cent), this variation was not statistically significant. This study found that 57 per cent of the households that owned an EV did not use a smart charger (see Figure 5-4). As 70 per cent of the households among the StrømFleks participants own an EV, and it being a flexible resource, it was surprising that only 42.4 per cent of them had moved charging to times with lower prices. One can assume that most of them have a private charging point as most households in the study own their own homes, and previous studies have found that 80 per cent of EVs are charged at home (Schulz & Rode, 2022). If the household drives their EV about 10.000 kilometres per year, using mainly their private charging point, it will consume about 2000 kWh a year (Statistics Norway, n.d.-e). Then, EV charging constitutes 10.5 per cent of the participant's yearly electricity consumption of 18.904 kWh in 2023. Hence, it was unexpected that the participants who own an EV and could see its consumption in the smart home technology app did not utilise this possibility to save money on their electricity bill. Further, shifting the time for when the EV is charged would provide demand-side flexibility and have less impact on the comfort of the household as it does not affect the temperature inside the home or when the hot water is being heated (Shove, 2003).

Based on the findings, participation in StrømFleks may correlate with a higher probability of changing behaviour to utilise the household's flexible resources. However, based on the lack of statistical significance related to changes in some household routines, H1 will be rejected. The steep increase in electricity prices during the pilot project period may have prompted more changes in household consumption compared to participation in the project alone. Additionally, the findings suggest that participants lacked knowledge about all the households' flexible resources and the optimal way to utilise them.

6.3 Factors that motivate or hinder household demand-side flexibility

The study found support for H2, that "Various factors, including trust, cost considerations, concerns about privacy, technology familiarity, and environmental concerns, influence households' willingness to provide demand-side flexibility". The factors that motivate or hinder the utilisation of demand-side flexibility (see Table 5-4) are derived from descriptive statistics, as some answering options had few responses. Hence, the study was not able to perform statistical analysis due to the method's requirement of a minimum cell count. Various factors that either hinder or motivate households were identified and investigated. Additionally, the implications for the stakeholders regarding the realisation of households' demand-side flexibility are examined.

The most important factor that influences demand-side flexibility is knowledge (see Figure 5-5). The households participating in the StrømFleks pilot project (85 per cent) were more willing to enter into an agreement to control flexible resources than the control group (27 per cent). In the control group, the respondents answered mainly that they were not willing (39 per cent) or uncertain (33 per cent) to enter into this kind of agreement. First, this finding shows that the StrømFleks participants who answered the questionnaire were satisfied with providing demand-side flexibility as they would continue to do so. Secondly, the results clearly reveal a difference in the groups' willingness, which was found to be statistically significant at the one per cent level. Billanes and Enevoldsen (2022) found knowledge to be one of the influential factors affecting behavioural intention of adopting smart energy technologies. As demand-side flexibility is a new concept for households, and the respondents in the control group reported fewer instalments of smart home technology, it is likely they have less knowledge about flexible resources in their homes and the implications of entering into agreements for their control. By participating in the project, the households have received information about flexibility, and they have gained knowledge through their experiences during the project. Knowledge about the benefits of utilising flexible resources can reduce households' electricity bills, as the new grid tariff makes it more costly for consumers who do not level out their consumption. The study found that the control group had made fewer changes in relation to the new grid tariff (see Figure 5-3) compared to the participants. This also indicates that the control group have less knowledge about how to level out their electricity consumption and utilise the flexible resources in their homes. Additionally, the study found that even the participants in the project did not have enough knowledge about demand-side flexibility and the best way to utilise it. The results regarding moving EV charging to off-peak hours to take advantage of lower prices (see Figure 5-3) and EV owners' use of a smart charger (see Figure 5-4) indicate a potential lack of knowledge or willingness among both groups to adopt changes associated with price-incentivised demand response. The findings in the study illustrate that price-incentivised demand response does not fulfil its purpose as households do not level out the consumption load. Within the control group, only 60 per cent had altered their daily routines to reduce electricity consumption. Additionally, 39 per cent reported that the new grid tariff had influenced their households' electricity usage, while among the 58 per cent who owned an EV, only 30 per cent had shifted their charging to off-peak hours with lower electricity prices. The abundance of renewable energy and relatively low electricity prices in Norway until 2020 may have contributed to the lack of knowledge (Ballo, 2015; Throne-Holst et al., 2008). Therefore, even if Norway was one of the first countries to have a liberalised electricity market, reflecting on consumption and its effect on the energy sector is a new matter for Norwegian households. It indicates that more knowledge about electricity consumption in general and demand-side flexibility specifically is needed to take advantage of its potential to assist the grid.

For the households that were willing to enter into an agreement to control the flexible resources, they were asked a follow-up question about which actor they would allow to control. In the literature, the role of an aggregator will be filled by the electricity producer or a new third party. In Norway, the distribution system operator cannot be an aggregator as they are in a monopoly situation in their region (StrømFleks workshop, 2024). The majority of the StrømFleks participants (69.7 per cent) would allow Lede control, the respondents from the control group would prefer Lede (15.2 per cent) or a governmental institution, and a few respondents from each group were uncertain of whom they would prefer (see Figure 5-6). The study was not able to perform statistical analysis for this question due to the low number of respondents who would prefer other entities than the grid owner and the requirement of a minimum cell count in the method. The descriptive statistics indicate that the StrømFleks participants trusted and were satisfied with Lede in the project, as Lede, by controlling the flexible resources, played the part of the aggregator in the pilot project. Further, the results indicate that the participants do not have enough knowledge about how the future scenario of the utilisation of demand-side flexibility and that the electricity company or a new third party will handle the aggregator role.

None of the respondents wanted the entities that would fulfil the role of an aggregator, the electricity company or a new third party to control their flexible resources. These findings can be an indication of a lack of trust towards electricity providers. This result can also be backed up by the fact that the reputation of the grid owner/electricity supplier/third party was the third most important factor that would influence the household's decision to enter an agreement (see Table 5-4). Households' trust in electricity providers depends on how the companies have performed in the past. They are measured by whether the households perceive the companies to be open and honest and whether they take customers’ interests into account (Steg et al., 2015). The electricity industry reached an all-time low in 2022, with accusations of electricity companies violating customers' rights and overcharging (Kaldestad, 2023). These allegations likely contributed to a decline in household trust in these companies, which serve as aggregators.

Knowledge and trust have been discussed as a factor that can hinder the utilisation of demand-side flexibility, and a third hindering factor is privacy. Based on the response to the question, “Which factors will influence the decision to enter an agreement on controlling flexible resources in the household?” (see Table 5-4), privacy was the second most important factor after economic factors. The installation of smart meters was met with great resistance in many countries as consumers were concerned about their privacy (Raimi & Carrico, 2016b). In Norway, the installation of smart meters did not meet much resistance, and it is completed, but this study found that privacy in relation to the utilisation of flexibility is a hindering factor. Other studies have also found privacy to be an issue for installing smart house technology and the adoption of the smart grid (Döbelt et al., 2015; Sovacool, 2021). Privacy issues can be related to data protection concerns, and the consumer requires that the data transmission is safe and transparent on how the data is handled and stored (Döbelt et al., 2015; Montakhabi et al., 2022). Furthermore, privacy issues are connected to the spatial privacy of the home associated with the private space and the right to behavioural and lifestyle privacy (Montakhabi et al., 2022). A home is more than just a shelter, and Gram-Hansen and Darby (2018) have distinguished four aspects of a home, a home is: “a place for security and control, for activity, for relationships and continuity, and for identity and values”. A large share of the homes in Norway are owned, and they are connected to some cultural norms like “your house creates possibilities for a good life” and “our home is our castle” (Throne-Holst et al., 2008, p. 61). Privacy issues, both data and spatial privacy, must be addressed so they do not become a barrier to utilising demand-side flexibility.

This study found that the economic factor was the most influential factor in the respondents' decision to enter into an agreement to control the flexible resources in the households (see Table 5-4). The economic factor can be both a hindrance and a motivation to utilise demand-side flexibility. It can be a hindrance as the investment cost of smart home technology involves a financial investment, which can lead to exclusion for some classes of the population (Sovacool, 2021). The smart home technology provided by Futurehome in the StrømFleks project cost 14.390 NOK per household, including the installation by an electrician. For the more complex smart home technologies such as price- and demand-driven systems for residential buildings, it is possible for private persons to get financial support up to 10.000 NOK by Enova (Enova, n.d.-c). These systems are more costly than the ones provided in the project. To receive financial support from Enova, the household will have to pay for the total cost upfront, provide the invoice for the equipment and work cost of the professional installer, and then the financial support provided by Enova will be calculated based on the documentation. Enova will cover up to 35 per cent of the documented cost of price- and demand-driven systems (Enova, n.d.-c). An upfront payment model can be a challenge for low-income households, and they will not receive financial support from Enova. These households risk being excluded from the possibility of using smart home technology to increase their knowledge of the household's electricity consumption and flexibility possibilities (Sovacool, 2021). Hence, the initial cost acts as a barrier for lower-income individuals to engage in environmental actions that could lead to long-term savings.

The economic factor can also be motivational, as prosumers would like to be compensated for their efforts to shift their energy usage and the service they provide to the grid. According to D'Ettorre et al. (2022), this will be an incentive-based demand response program. The prosumers partake in the co-creation of demand-side flexibility that has value in the power market (Kubli et al., 2018). As a household is too small to sell its demand-side flexibility independently in the market, it depends on the aggregator to create bundles of flexibility from many small household units (Niesten & Alkemade, 2016). This study's findings indicate that households would like to be economically compensated for the value they co-create together with the aggregators.

The societal, natural and environmental factors were found to be "important" but not "very important" for the respondents' decision to enter into an agreement to control flexible resources. These findings and the sample of respondents in this study, who are mostly highly educated (see Table 5.1), correspond with previous studies that found that knowledge predicts more pro-environmental behaviour (Gifford & Nilsson, 2014). Incentives to encourage households with altruistic and environmental values and motivations to provide demand-side flexibility should be initiated.

Half of the respondents found technology understanding to be "important" but not among the most influential factors in their decision to enter into an agreement on control of flexible resources. Besides financial investment, lack of technology understanding and the skills required to utilise, for example, smart home technology and apps, can lead to vulnerability and social exclusion for some classes (Sovacool, 2021). Based on this finding, stakeholders may explore ways to raise households' technology literacy to include them in the smart grid and take advantage of the technologies' benefits in terms of comfort control and convenience (Nikou, 2019b).

6.4 Implications for stakeholders to the co-creation of demand-side flexibility

As consumers shift their electricity load to free up grid capacity, they become prosumers (Kubli et al., 2018). To utilise the prosumers' demand-side flexibility, the prosumers become co-creators together with the aggregators to deliver their flexibility to the market. The value must be created for both prosumers and aggregators for them to move in the same direction. Analysing stakeholder connections related to the utilisation of household demand-side flexibility can help identify implications for different stakeholders for the shared objective to be realised. This study will use stakeholder theory with an issue-centric approach to analyse the drivers and barriers to the utilisation of household demand-side flexibility (Mihailova et al., 2022; Olkkonen et al., 2017). Based on issue-centric stakeholder relationships, literature review, and the findings from this study, the following stakeholders in demand-side flexibility have been identified: the co-creators of demand-side flexibility, prosumers and aggregators, policymakers, Enova, distribution system operators, electricity providers, smart home technology providers, providers of smart EV chargers, the marketplace actors, nature, and society (see Figure 6-1).

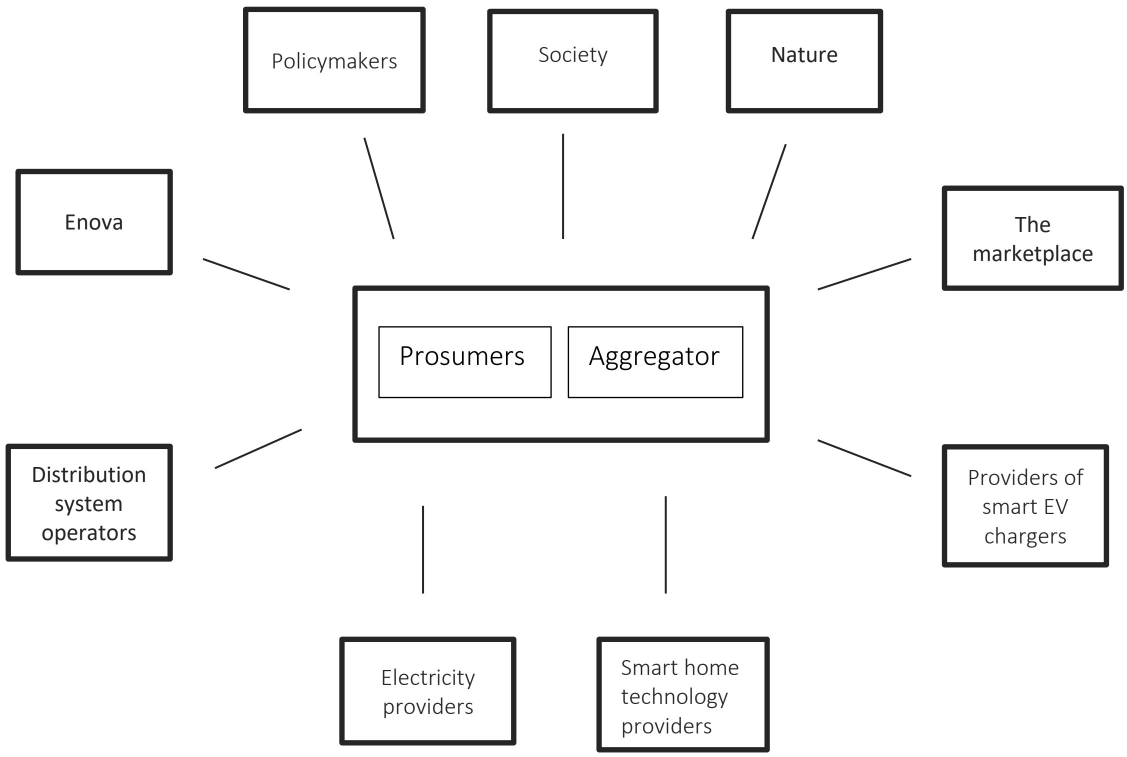

Figure 6-1 Stakeholders in the co-creation of demand-side flexibility to the market.

Note: Based on issue-centric stakeholder relationships (Mihailova et al., 2022; Olkkonen et al., 2017) and the analysis of factors that hinder or motivate the utilisation of demand-side response.

National and local policymakers must develop effective strategies and regulations for demand-side flexibility that consider the values of all stakeholders as regulations are still looked into (Energidepartementet, 2021). It is preferable with a special focus on households, as the most vulnerable stakeholder, to ensure their spatial privacy. White papers and governmental bodies have pointed out that technical solutions, households as active participants and flexibility as a possible way to balance the grid are among the suggested measures to achieve the goal of a low-emission society by 2025 (Energidepartementet, 2021; Miljødepartementet, 2023; Norges offentlige utredninger, 2023). Therefore, based on the findings in this study, policymakers should implement measures to increase household knowledge related to energy efficiency and enhance incentives beyond Enova for financial support towards household adoption of smart home technologies.

The stakeholders in the energy sector should continue their work with information regarding energy consumption and demand-side flexibility. The distribution system operators and electricity providers have good information on their web pages, and consumers who seek this information find what they require (Fjordkraft, n.d.; Lede, 2023b). The electricity providers make electricity consumption visible in their apps, and to increase households' knowledge, they can encourage and teach customers to use the apps. If the objective of demand-side flexibility to the market is not realised, one implication for the distribution system operator will be less capacity available in the existing grid, and the waiting list for businesses who need more capacity for their energy transition or to expand will maintain (Westhrin, 2024).

For the management of the different stakeholders related to smart home technology and smart charging businesses, the results of the analysis found it is important that both data and spatial privacy of the households are well looked after. These businesses should be transparent about how the data is handled and stored to establish trust between them and the households. Incentives towards households to invest in smart home technology incentives should target households that own the house they live in, as the likelihood of investing in energy-efficient measures increases with home ownership (Niamir et al., 2020). Further, the results of this study indicate that these businesses should develop technologies that are easy to use and participate in increasing the household's technology understanding.

The findings in the study indicate that the reputation of the aggregator can become a barrier to the utilisation of demand-side flexibility. The aggregator is a co-creator together with the prosumer in providing demand-side flexibility to the market. In the co-creation of demand-side flexibility, the boundaries between private lives and businesses become interconnected and blurred (Freeman & McVea, 2005). Trust between the prosumer and the aggregator is essential, especially as there is a power difference between the households and a registered business. The aggregator needs to establish trust between them and the prosumers as prosumers might judge them on how they performed in the past, and trust is essential as it leads to lower transaction costs between the co-creators (Rothstein & Holmberg, 2020; Steg et al., 2015). To establish trust towards the prosumer, the aggregator needs to be open and honest and prove that they take the interest of the prosumer into account. In addition to establishing trust, the aggregator needs to provide the right incentives to the prosumers. The analysis suggests that economic incentives would be most appropriate, but prosumers with altruistic and environmental values can find other incentives, like green deals, more agreeable.

In a complex energy system like the smart grid, where boundaries between businesses and private lives become blurred, the different stakeholders identified in this study have a role to play in the realisation of household demand-side flexibility. If the potential is not realised, there will be no need for a marketplace for flexibility as the prosumer households are too small of an actor to trade their own flexibility (Kerscher & Arboleya, 2022). Society might suffer as there will be less capacity in the grid for businesses that need electricity for their energy transition or to establish themselves, which can lead to fewer jobs, for example, in the industrial region of Grenland (Hella, 2023; Herøya Industripark, n.d.-a) Lastly, nature will be affected as the grid needs to be expanded to accommodate the increased capacity needed for the energy transition (Statkraft, 2023). If the capacity and stability of the grid are not able to incorporate renewable energy sources, it can reduce the chance of achieving the goal of reducing greenhouse gas emissions to limit global warming to 1.5 degrees (United Nations, 2023).

7 Conclusion

Transitioning from fossil fuels to renewable energy sources is essential to limit global warming, but it poses challenges like storage limitations and fluctuation due to weather patterns. Demand-side flexibility plays a crucial role in ensuring grid stability. Industrial customers' demand-side flexibility has been utilised for decades, but the potential of small-scale customers like households has not been exploited. Understanding human behaviour is essential for an individual's acceptance and utilisation of demand-side flexibility. This study explores how participation in a pilot project managing flexible resources influences household behaviour and identifies motivating and hindering factors in the utilisation of household demand-side flexibility.

The StrømFleks pilot project in Porsgrunn, Norway, serves as the case study. A comparative approach is applied, contrasting participants to a control group of non-participants. Primary data was obtained via an online questionnaire to compare the groups' behaviour and attitudes. While the empirical study is a case study, its insights benefit energy supply chain managers and policymakers. Norway's experience, with its renewable energy dominance, a market-based electricity system, mature EV market, and smart grid infrastructure, provide valuable lessons for countries aiming to increase their renewable energy shares and decarbonise.

Several conclusions can be drawn from the empirical findings. First, the households exhibit limited knowledge and awareness regarding their electricity consumption and use of flexible resources. Moreover, they exhibited more changes in behaviour, with 82 per cent altering routines to limit electricity consumption compared to 61 per cent in the control group. Additionally, the participants showed a higher willingness (85 per cent) to enter agreements controlling flexible resources, contrasting with only 27 per cent in the control group. These findings suggest that with knowledge and experience managing flexible resources, household demand-side flexibility can be utilised.

The second conclusion suggests that smart EV charging as a flexible resource must be enhanced. The analysis found that the participants performed several changes to shift the households' flexible resources, but EV charging was performed the least as 70 per cent of the participants own an EV, but only 42 per cent charged off-peak. Considering the participants reported electricity consumption in 2023, EV charging could account for

10 per cent of their consumption. Therefore, promoting smart chargers among EV owners has significant potential for demand-side flexibility.

The third conclusion is the importance of economic incentives to promote household demand-side flexibility, which was identified as the most motivational factor. The literature showed that households want to be compensated for their behavioural change and service provided to the grid. Furthermore, other motivational factors include societal, natural, and environmental considerations. Appropriate incentives should be created to attract households with altruistic and environmental values.

The fourth conclusion is that data and spatial privacy issues are a potential barrier to demand-side flexibility, as privacy was found to be the second most important factor for the respondents. Hence, it is important that utility companies, aggregators, and smart technology providers prioritise this factor to establish trust with households.

The fifth conclusion suggests that trust in aggregators may hinder demand-side flexibility. Aggregators, whether the electricity provider or a new third party, must establish trust with prosumer households who act as co-creators. Given the declining reputation of electricity providers in the last few years, prosumers might judge them on their past performance, emphasising the need for aggregators to prioritise trust-building efforts.

Stakeholder management is vital in the intricate dynamics of a smart grid system. Therefore, a stakeholder theory approach with the issue-centric perspective on household demand-side flexibility was employed. This approach facilitated the examination of various stakeholders' impact on the adoption and utilisation of household demand-side flexibility, which depends on co-creation between prosumers and aggregators, as well as interactions with other stakeholders. Based on the study's findings, the following implications for the stakeholders concerned with household demand-side flexibility are suggested: Policymakers, national and local, need to formulate effective strategies and regulations, with special attention to households and their spatial privacy within the context of the smart grid. Additionally, policymakers should implement measures aimed at enhancing households' understanding of electricity consumption, strengthening incentives to adopt smart home technology, and providing education for technology-illiterate households. Stakeholders in the energy sector should intensify efforts to improve households' understanding of electricity consumption, flexible resource utilisation, and the importance of demand-side flexibility. The energy sector should explore alternative communication channels and encourage the use of apps that visualise energy consumption. While price-demand programs are in place, these do not seem to have the desired effect, as households are not shifting their consumption load. The study's findings showed that within the control group, only 60 per cent had altered their routines to reduce electricity consumption. Additionally, 39 per cent reported that the new grid tariff had influenced their households' electricity usage, while among the 58 per cent who owned an EV, only 30 per cent had shifted their charging to off-peak hours with lower electricity prices. Moreover, for the energy sector, the study suggests conducting further pilot projects with a larger number of participants and emphasising observing changes in participants' behaviour alongside technical aspects. It is recommended to gather data at the start of the project and include a control group to assess behavioural changes during the project. Additionally, conducting more post-evaluations with scientific monitoring is advised.

Research institutions, including universities and other nationally approved research organisations, are advised to seek closer collaboration with energy sector entities to enhance energy-related knowledge. The media, both national and local, play a significant role in knowledge dissemination. By publishing well-researched and informative articles related to energy-related subjects accompanied by clear explanations of complex terminology, media can enhance households' knowledge. The management of businesses related to smart technology ought to address privacy issues, develop user-friendly interfaces, and facilitate technological literacy among households. Ensuring that all households can partake in technological advancement and learn about energy efficiency and flexible resources is essential for making informed economic and environmental decisions.

The primary limitation of this study is the low number of respondents to the questionnaire; there were 33 respondents among StrømFleks and 33 respondents in the control group. A second limitation was that the data for electricity consumption for 2019 was based on retrospective reporting. Recommendations for further research include expanding the sample size and dataset to enable generalisability and enhance the understanding of consumer behaviour concerning demand-side flexibility. Future studies should be carried out in collaboration with established researchers in this field, and the data should be collected in different phases of the project implementation.

Declaration of competing interest

The author declares that no known competing financial interests or personal relationships could have influenced the work of this study.

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Appendix

Appendix 1: <Information Letter to the StrømFleks participants>

The invitation and information regarding participation in the questionnaire were sent in an email from Lede to the StrømFleks participants.

In the process of translating the information letter from Norwegian to English, "ChatGPT" (2024) was used, and the text was proofread by the researcher.

Hello to all participants in the StrømFleks project,

In connection with the StrømFleks project, we are collaborating with a master's student from the University of South-Eastern Norway (USN), who is writing her master's thesis to explore the implications of the Strømfleks project. We hope you can spare some time to assist the student in gathering responses, which will contribute to a high-quality investigation.

The survey is distributed to participants in StrømFleks and a control group of 150 households who did not participate in the project to investigate the impact of StrømFleks. The questionnaire takes 10-15 minutes, and you will have 10 days to respond. A reminder will be sent out 3 days before the deadline. By participating, you can receive a summary of the results at the end of the project if you wish, and you'll also enter into a drawing for a gift card worth 500 NOK at Down Town. If you have any questions regarding the questionnaire, please reply to this email or contact master's student Malin Høiseth at 253187@usn.no or by phone at 40606114.

To participate in the questionnaire, click here.

Thank you for your time! Wishing you a great week!

Appendix 2: < Questionnaire Consent and Information Letter>

Information about the survey was posted in the Facebook group "Porsgrunn Today" ("Porsgrunn i dag") to recruit the control group of 150 non-participating households in the project.

In the process of translating the information letter from Norwegian to English, "ChatGPT" (2024) was used, and the text was proofread by the researcher.

Hello! Right now, I am working on my master's thesis in Sustainable Management at the University of Southeast Norway, and I hope you can help me by answering a questionnaire about how your household uses electricity. The questionnaire takes 10-15 minutes, is completely anonymous, and you can enter into a draw for a gift card to Down Town worth 500 NOK and receive a summary of the results when the project is finished. Here is the link to the survey, which is open for 10 days: [link]

Thank you very much for wanting to contribute with your answers!
In my thesis, I am investigating changes in electricity consumption among 150 households participating in the power company Lede's pilot project StrømFleks, compared to 150 non-participating households. I am collaborating with Lede to distribute the survey to the participants in StrømFleks, and your participation will help to form a group of non-participating households.
The StrømFleks project took place in Porsgrunn from 2020 to 2023. It investigated the effect of smoothing out electricity consumption for better power grid utilisation by installing smart home solutions and adjusting the timing of electricity consumption, for example, for water heaters, heat pumps, and heating cables. Changes in electricity prices and a new grid tariff model influenced everyone's electricity consumption during this period. Now, I want to explore whether these two groups have differences in electricity consumption.
Your participation is of great importance to my research. Thank you again for your interest and participation in the questionnaire! If you have any questions, please contact me, Malin Høiseth.

The following consent information was given at the beginning of the questionnaire: "How does your household use electricity?"

In the process of translating the information letter from Norwegian to English, "ChatGPT" (2024) was used, and the text was proofread by the researcher.

Welcome to the questionnaire.
The transition to renewable energy and increased electrification requires expansion and improved power grid utilisation. Pilot projects, like StrømFleks (2020-2023), explore ways to streamline the grid to reduce the need for expansion. The project investigated the

management of flexible resources such as water heaters, heat pumps, panel heaters, and underfloor heating using smart home technology to relieve pressure on the power grid. The survey you are about to complete is part of a new study aiming to examine changes in behaviour among the 150 participants in StrømFleks and 150 non-participating households. By completing the questionnaire, you consent to processing your information until the project is completed. All information is processed anonymously, and only the student and supervisor have access before anonymization. On behalf of USN, Sikt – the knowledge sector's service provider, has assessed that the processing of personal data in this project complies with privacy regulations. We appreciate your taking the time to answer some questions about electricity usage in your household.

The following consent information was given at the end of the survey.

Participation in the project is voluntary, and you can withdraw your consent at any time without giving a reason. Your personal information will be deleted upon withdrawal without any negative consequences. All information is treated anonymously, and only the student and supervisor have access before anonymisation. You have the right to access, correct, and delete your information, as well as complain to Datatilsynet. The project ends on July 31, 2024, and the data will be anonymised thereafter.

If you have any questions about the study or wish to exercise your rights, please contact The University of Southeastern Norway, by Master student Malin Høiseth, by email at 253187@usn.no or by phone at 40606114. If you have questions regarding the assessment conducted by Sikt's privacy services, contact them via email: personverntjenester@sikt.no or phone: 73 98 40 40.

Appendix 3: < Questionnaire - How does your household use electricity?>

In the process of translating the questionnaire from Norwegian to English, "ChatGPT" (2024) was used, and the text was proofread by the researcher.

1. **Ownership status of the home in which the household lives:**

- Owner-occupied
- Rented
- Other

INFO: Following are some questions related to electricity consumption and behaviour. The year 2019 is used because it predates the start of the StrømFleks project, increased electricity prices, and the new grid tariff model, and 2023 is used because it is the latest consumption year.

2. **Do you know, without checking, how many kWh your household used in 2019?**

Write the answer in numbers without commas or periods. If you do not know, write zero with numbers.

3. **Do you know, without checking, how many kWh your household used in 2023?**

Write the answer in numbers without commas or periods. If you do not know, write zero with numbers.

4. **Has the household changed daily routines to limit electricity consumption?**

- Yes
- No

5. **If the household changed daily routines to limit electricity consumption, which routines have been changed?**

The following routines only appear if "Yes" is selected in question 4.

	Have done this	Have not done this
Turned off lights in unused rooms		
Turned off heating in rooms not used daily		
Lowered temperature in the home		
Increased use of other heat sources than electricity, e.g., wood		
Used less hot water for showering		
Prepared dinner at different times		
Reduced electricity consumption for cooking		
Moved energy-intensive tasks such as laundry and dishwasher to times with lower electricity prices		
Moved electric car charging to times with lower electricity prices		

6. **Has the household changed electricity supplier in the last five years?**

- Once
- Multiple times
- No
- Don't know

INFO: In July 2022, a new grid tariff model was introduced to increase the utilisation of the power grid by evenly distributing electricity consumption throughout the day.

7. **Has the new grid tariff model influenced how electricity is used in the household?**

- Yes, we have set limitations in the app for smart energy management
- Yes, we have evened out electricity consumption to limit capacity charges
- No, use electricity in the same way as before the new grid tariff model
- Not aware of the new grid tariff model
- Do not know

INFO: Now, we will ask you questions about your attitude towards technology.

8. **When it comes to new technologies, how would you describe yourself?**

- I'm always on the lookout for the latest technologies
- I'm fairly quick to follow technology trends
- I join in when most people have already tried it out
- I go with the flow and adopt technology trends when they are well-established
- I take my time before starting to use new technologies

9. Does the household use smart home solutions/technology?

- Yes
- No
- Don't know

10. What motivates the household to use smart home solutions/technology?

These motivations only appear if "Yes" is selected in question 9.

Please select the option that best fits the household's motivation for each.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Technological interest					
Increasing knowledge about energy consumption					
Economic interest					
Ability to control electricity consumption					
Assisting the local power grid					
Environmental considerations					
Making daily life easier					

11. Does the household own an electric car and use smart charging?

- Yes

- Owns an electric car but does not use smart charging
- No

INFO: Flexibility in the power grid means considering various solutions to utilize the power grid's capacity in the best possible way. Efficient utilisation of capacity will free up capacity for those who need it and limit the need for costly expansion and environmental impact. Regarding households, consumer flexibility means actively adapting to even electricity consumption throughout the day. Household flexible resources include water heaters, heat pumps, underfloor heating, and electric car chargers where connections can be shifted to distribute daily electricity consumption without affecting home comfort.

12. **Is the household willing to change its electricity consumption to free up more capacity in the power grid?**
    - Yes
    - Partially
    - No
    - Don't know
13. **Is the household willing to enter into an agreement with the grid owner/electricity supplier/third party to manage electricity usage in the household, provided it does not affect comfort?**
    - Yes
    - No
    - Don't know
14. **To utilize flexibility, which devices will the household accept to be controlled by the network company/electricity supplier/third party?**

    The following devices only appear if "Yes" is selected in question 13.

	Yes	No
Water heater		
Heat pump		
Underfloor heating		
Panel heaters		
Electric vehicle charger		

15. **If the household were to let someone else control the flexibility, who should it have been?**

This item only appears if "Yes" is selected in question 13.

- The grid company, Lede
- The electricity supplier
- A new actor
- A governmental institution
- Don’t know

16. When controlling flexible resources like those mentioned above, how would the household prefer them to be managed?

This item only appears if "Yes" is selected in question 13.

- Fully automatic by others (e.g., network company/electricity supplier/third party)
- Partially automatic by others (e.g., network company/electricity supplier/third party), but with the ability to override when necessary
- Manually controlled/programmed by the household in a smart home app

17. Which factors will influence the decision to enter an agreement on controlling flexible resources in the household?

Rate each factor based on its importance to the household.

	Very important	Important	Neutral	Less important	Not important
Nature and environment					
Social					
Economic					
Understanding of technology					
Privacy					
Reputation of the grid owner/electricity supplier/third party					
Personal social image/reputation					

18. What motivational factors will be crucial for allowing external control of flexibility?

Rate each factor based on its importance to the household.

	Very important	Important	Neutral	Less important	Not important
Economic compensation					

Opportunity to have an agreement for using only green/sustainable electricity					
Getting information and contributing to good electricity usage					
Knowing that one contributes to better utilisation of the power grid					
Knowing that one contributes to the environment and society					

BACKGROUND: For statistical analysis, we will finally ask some questions about you and your household.

19. What is your gender?

- Female
- Male
- Other

20. What is your age?

- 18-24 years
- 25-35 years
- 35-44 years
- 45-54 years
- 55-64 years
- 65+

21. What is the highest education level in the household?

- Primary school
- Vocational school/high school
- Bachelor's degree or equivalent
- Master's degree or higher

22. What is the household's total gross annual income (i.e., before tax)?

- Less than 600,000
- 600,000 – 1,000,000
- 1,000,000 – 1,400,000

- 1,400,000 – 2,000,000
- Over 2,000,000
- Prefer not to disclose

23. Did the household participate in the StrømFleks project?

- Yes
- No

The remaining questions only appear if "Yes" is selected in question 23.

24. What was the main reason for the household to participate in the StrømFleks project?

- The opportunity to have a smart home control system installed
- Curiosity about technology
- Economically profitable
- Helping the local power grid
- Good for the environment and nature

25. Has Lede's disconnection of flexible resources affected the household's comfort?

- No, comfort has not been affected at all
- Yes, comfort has been affected on a few occasions
- Yes, comfort has been affected on many occasions
- Don't know

26. After the completion of the StrømFleks project, has the household continued to shift consumption of flexible resources to times with low electricity prices?

Rate the extent to which the household has shifted consumption

High level of compliance	Some compliance	Neutral	Low compliance	No compliance

27. How satisfied are you with participating in the StrømFleks project?

Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied	Not applicable/cannot answer

28. After participating in StrømFleks, would you recommend others to install smart home solutions/technology and utilize flexible resources?

- Yes

- No
- Don't know

29. **If we do not achieve enough participants in the survey, would you be willing to participate in an interview about changes in electricity consumption and behaviour?** Feel free to leave your email address or phone number. This information will be deleted when the project is over.
30. **If you wish to receive a summary of the survey results, please leave your email address.** This information will be deleted when the project concludes.
31. **If you would like to participate in the draw for a gift card from Down Town worth 500 kroner, please leave your email address**.

    This information will also be deleted when the project ends.

Appendix 4

Table A4-1 Full probit estimates of the determinants of the likelihood of knowing electricity consumption (N = 130).

	Coeff.	Stand. Err.	z -stat	P>z	[95% conf.interval]	
StrømFleks	-0.010	0.342	-0.03	0.978	-0.679	0.660
Year2023	0.184	0.337	0.55	0.585	-0.476	0.844
StrømFleks X year2023	0.213	0.476	0.45	0.655	-0.719	1.145
35 to 44 years	-0.202	0.421	-0.48	0.631	-1.028	0.624
45 to 54 years	0.026	0.405	0.06	0.949	-0.768	0.820
55 to 64 years	0.090	0.462	0.19	0.846	-0.815	0.995
65 years and older	-0.164	0.436	-0.38	0.706	-1.018	0.690
Master's degree / Ph.D.	-0.294	0.243	-1.21	0.225	-0.771	0.182
Woman	-1.200	0.282	-4.25	0	-1.753	-0.647
Constant	0.625	0.475	1.31	0.189	-0.307	1.557

Number of observations: 130. Pseudo R2: 0.158.
Note: The number of observations is 130 as the knowledge of electricity consumption is recorded for the years 2019 and 2023, respectively, with 65 observations per year.
Source: Own survey.

Table A4-2 Full marginal effects of the likelihood of knowing electricity consumption (N = 130).

	dy/dx	std. err.	z-stat	P>z	[95% conf.	interval]
StrømFleks	0.031	0.090	0.35	0.73	-0.145	0.206
Year2023	0.094	0.077	1.21	0.225	-0.058	0.245
StrømFleks X year 2023	0.065	0.122	0.53	0.594	-0.174	0.304
35 to 44 years	-0.066	0.137	-0.48	0.63	-0.334	0.203
45 to 54 years	0.008	0.132	0.06	0.949	-0.250	0.267
55 to 64 years	0.029	0.151	0.19	0.846	-0.266	0.324
65 years and older	-0.054	0.142	-0.38	0.706	-0.332	0.225
Master's degree / Ph.D.	-0.096	0.078	-1.23	0.219	-0.249	0.057
Woman	-0.391	0.071	-5.53	0	-0.530	-0.253

Note: dy/dx for factor levels is the discrete change from the base level.
Number of observations: 130.
Note: The number of observations is 130 as the knowledge of electricity consumption is recorded for the years 2019 and 2023, respectively, with 65 observations per year.
Source: Own survey.

Table A4-3 Full difference-in-differences estimations of the effect of the StrømFleks pilot project on electrical consumption (N = 65).

DIFFERENCE-IN-DIFFERENCES ESTIMATION RESULTS				
Number of observations in the Diff-in-diff: 65				
	Before	After	Total	
Control group	13	15	28	
StrømFleks	16	21	37	
Total	29	36		
Outcome variable	ln kwh	S. Err.	t	P>t
Before				
Control group	10.053			
StrømFleks	9.891			
Diff (T-C)	-0.162	0.129	-1.25	0.216
After				
Control group	9.953			
StrømFleks	9.849			
Diff (T-C)	-0.104	0.12	0.87	0.387
Diff-in-Diff	0.057	0.176	0.32	0.747
R-square	0.05			

*Means and Standard Errors are estimated by linear regression.

**Robust Std. Errors.
***Inference: ***p<0.01; **p<0.05; *p<0.1
Source: Own survey.

Table A4–4 Full cross-tabulation and chi-square test: Question 4 (see Appendix 3) "Has the household changed daily routines to limit electricity consumption?" (N = 66).

	StrømFleks	Control group	Total
Yes	27	20	47
No	6	13	19
Total	33	33	66

Pearson chi2(1) =	3.62	Pr = 0.057
Likelihood-ratio chi2(1) =	3.69	Pr = 0.055
Cramér's V =	-0.23	
gamma =	-0.49	ASE = 0.218
Kendall's tau-b =	-0.23	ASE = 0.117
Fisher's exact =		0.102
1-sided Fisher's exact =		0.051

Source: Own survey.

Table A4–5 Full cross-tabulation and chi-square test: Question 7 (see Appendix 3) "Has the new grid tariff influenced the households' electricity consumption?" (N = 66).

	StrømFleks	Control	Total
No	11	20	31
Yes	22	13	35
Total	33	33	66

Pearson chi2(1) =	4.93	Pr = 0.026
Likelihood-ratio chi2(1) =	4.99	Pr = 0.025
Cramér's V =	0.27	
gamma =	0.51	ASE = 0.190
Kendall's tau-b =	0.27	ASE = 0.118
Fisher's exact =		0.048
1-sided Fisher's exact =		0.024

Source: Own survey.

Table A4-6 Full cross-tabulation and chi-square tests Question 5 (see Appendix 3) "Moved energy-intensive tasks such as laundry and dishwasher to times with lower electricity prices" (N = 46).

	StrømFleks	Control group	Total
Yes	18	13	31
No	8	7	15
Total	26	20	46

Pearson chi2(1) =	0.09	Pr =	0.762
Likelihood-ratio chi2(1) =	0.09	Pr =	0.762
Cramér's V =	-0.04		
gamma =	-0.10	ASE =	0.313
Kendall's tau-b =	-0.04	ASE =	0.148
Fisher's exact =			1
1-sided Fisher's exact =			0.503

Source: Own survey.

Table A4-7 Full cross-tabulation and chi-square test Question 5 (see Appendix 3): "Moved electric car charging to time with lower electricity prices" (N = 43).

	StrømFleks	Control group	Total
Yes	14	9	23
No	10	10	20
Total	24	19	43

Pearson chi2(1) =	0.51	Pr =	0.474
Likelihood-ratio chi2(1) =	0.51	Pr =	0.474
Cramér's V =	-0.11		
gamma =	-0.22	ASE =	0.295
Kendall's tau-b =	-0.11	ASE =	0.152
Fisher's exact =			0.547
1-sided Fisher's exact =			0.342

Source: Own survey.

Table A4-8 Full cross-tabulation and chi-square tests Question 11 (see Appendix 3) Does the household own an electric vehicle and use a smart charger? (N = 66).

	StrømFleks	Control group	Total
Owns an EV but does not use a smart charger	12	12	24
Yes	11	7	18
No	10	14	24
Total	33	33	66

Pearson chi2(2) =	1.56	Pr =	0.459
Likelihood-ratio chi2(2) =	1.57	Pr =	0.457
Cramér's V =	0.15		
gamma =	-0.12	ASE =	0.199
Kendall's tau-b =	-0.07	ASE =	0.116
Fisher's exact =			0.478

Source: Own survey.

Table A4-9 Full cross-tabulation and chi-square test: Question 13 (see Appendix 3) "Is the household willing to enter into an agreement with a grid owner/electricity supplier/third party to manage electricity usage in the household, provided it does not affect the comfort?" (N = 66).

	StrømFleks	Control group	Total
Yes	28	9	37
No	4	13	17
Don't know	1	11	12
Total	33	33	66

Pearson chi2(2) =	22.85	Pr =	0.000
Likelihood-ratio chi2(2) =	25.01	Pr =	0.000
Cramér's V =	0.59		
gamma =	-0.85	ASE =	0.082
Kendall's tau-b =	-0.56	ASE =	0.087
Fisher's exact =			0.000

Source: Own survey.

Table A4-10 Full cross-tabulation: Question 15 If the household were to let someone else control the flexibility, who should it have been? (N = 37).

	StrømFleks	Control group	Total
Grid owner, Lede	23	5	28
Governmental institution	0	1	1
Don't know	5	3	8
Total	28	9	37

Source: Own survey.

Table A4-11 Cross-tabulation of the participants in StrømFleks' factors that motivate or hinder the utilisation of demand-side flexibility (N = 33).

	Very important	Important	Neutral	Less important	Of no importance	Total
Economic	18	11	3	0	1	33
Privacy	14	9	4	4	2	33
The reputation of the grid owner/electricity supplier/third-party	8	11	10	0	4	33
Societal	6	17	5	4	1	33
Nature and environment	4	13	11	3	2	33
Technology understanding	7	15	9	1	1	33
Own social image	1	5	12	6	9	33

Source: Own survey.

Table A4-12 Cross-tabulation of the control groups' factors that motivate or hinder the utilisation of demand-side flexibility (N = 32).

	Very important	Important	Neutral	Less important	Of no importance	Total
Economic	14	13	4	1	0	32
Privacy	11	7	9	3	2	32
The reputation of the grid owner/electricity supplier/third-party	9	7	10	5	1	32
Societal	3	7	13	7	2	32
Nature and environment	4	11	6	6	5	32

Technology understanding	0	11	16	4	1	32
Own social image	2	1	17	4	8	32

Source: Own survey.