



Degree Project in Strategies for Sustainable Development

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Social drivers of the acceptability of demand-side flexibility in residential use in France

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Abstract

As the proportion of less predictable renewable sources in the French electricity network increases, the need for flexibility arises. Demand-side flexibility (DSF) from residential users offers a cost-effective and environmentally sustainable alternative to relying on thermal power plants.

This master thesis aims to identify and understand the factors and mechanisms that determine the acceptability and development of demand-side flexibility (DSF) among French households, in order to inform strategies for increasing DSF adoption and facilitate its future modelling. The study was conducted by combining a structured literature review with a survey conducted on a representative sample of the French population. Although the survey was conducted prior to my research period, this is the first time the results are being analysed in a publicly available document.

Findings reveal that barriers and incentives depend strongly on the flexibility method. For automated solutions, major obstacles include equipment requirements, privacy concerns related to data sharing, and perceived loss of control. In contrast, manual DSF is mainly hindered by inconvenience due to the disruption of daily routines. The economic barrier due to inadequate electricity tariffs and additional costs is also to be overcome. For the drivers, the cost savings are mentioned in almost all studies as a key incentive. The environmental benefits, and the evolution of habits for manual flexibility, also appear as important incentives for households.

Socio-demographic factors (age, income...), household structure and organisation (dwelling type, presence of children, working from home...), and moral values (environmental awareness, trust...) also significantly influence willingness to participate in DSF schemes. Furthermore, the temporal dimension matters: for example, willingness to shift practices to midday is greater among those working from home, whereas being at home does not have the same influence for shifting to late evening hours.

Finally, households' specific characteristics affect their perception and potential for flexibility: organisational constraints differ (e.g., noise issues are more significant in apartments), and tenants often face higher obstacles to automated DSF due to limited control over appliances.

Overall, these insights highlight the importance of tailoring DSF programs to households' characteristics and preferences in order to unlock greater flexibility potential. They can also directly inform the modelling of electricity networks in prospective studies, thus supporting the energy transition.

Keywords: Electricity, Demand-side flexibility, Demand response, Acceptability, Theory of social practices, Residential

Sammanfattning

I takt med att andelen mindre förutsägbara förnybara energikällor i det franska elnätet ökar, uppstår ett behov av flexibilitet. Flexibilitet på efterfrågesidan (Engelska: demand-side flexibility, DSF) från hushållskunder erbjuder ett kostnadseffektivt och miljömässigt hållbart alternativ till att förlita sig på värmekraftverk.

Denna masteruppsats syftar till att identifiera och förstå de faktorer och mekanismer som påverkar acceptansen och utvecklingen av DSF land franska hushåll, i syfte att informera om strategier för att öka användningen av DSF och underlätta framtida modellering. Studien genomfördes att kombinera en strukturerad litteraturgenomgång med en enkätundersökning som har genomförts på ett representativt urval av den franska befolkningen. Även om undersökningen genomfördes före min forskningsperiod analyseras dessa resultat här för första gången i ett offentligt dokument.

Resultaten visar att hinder och incitament i hög grad beror beror på vilken metod för flexibel elanvändning som implementeras. För automatiserade lösningar är de största hindren utrustningskrav, integritetsfrågor relaterade till datadelning och upplevd förlust av kontroll. Manuell DSF (det vill säga...) hindras däremot främst av besvär till följd av störningar i de dagliga rutinerna. Ekonomiska hinder på grund av otillräckliga eltariffer och extra kostnader måste också övervinnas. När det gäller drivkrafterna nämns kostnadsbesparingar i nästan alla studier som ett viktigt incitament. Miljöfördelarna och förändringar i hushållens organisation för manuell flexibilitet framstår också som viktiga incitament för hushållen.

Sociodemografiska faktorer (t.ex. ålder, inkomst), hushållets struktur och organisation (t.ex. bostadstyp, barn i hushållet, hemarbete) och moraliska värderingar (t.ex. miljömedvetenhet, förtroende) har också stor inverkan på viljan att delta i DSF-program. Dessutom spelar den tidsmässiga dimensionen roll: till exempel är viljan att flytta sina aktiviteter till middagstid större bland dem som arbetar hemifrån, medan det faktum att man är hemma inte har samma inverkan när det gäller att flytta aktiviteterna till sena kvällstimmar.

Slutligen påverkar hushållens specifika egenskaper deras uppfattning om och potential för flexibilitet: organisatoriska begränsningar varierar (t.ex. är bullerproblem mer betydande i lägenheter) och hyresgäster möter ofta större hinder för automatiserad DSF på grund av begränsad kontroll över apparater.

Sammantaget understryker dessa insikter vikten av att anpassa DSF-program till hushållens egenskaper och preferenser för att frigöra större flexibilitetspotential. De kan också direkt informera modelleringen av elnät i framtida studier och därmed stödja energiomställningen.

Nyckelord: El, Flexibilitet på efterfrågesidan, Efterfrågerespons, Acceptans, Teori om sociala praktiker, hushåll

Table of contents

Acknowledgement	1
Abstract.....	2
Sammanfattning.....	3
Table of contents	4
Abbreviations	5
1. Introduction.....	6
1.1. Background	6
1.2. Literature review: highlighting research gaps.....	7
1.3. Aim	10
1.4. Study context	10
1.5. Structure	10
2. Theoretical framework	11
2.1. Key concepts	11
2.2. Framing demand-side flexibility from user’s perspective	15
3. Methodology	21
3.1. Structured literature review	21
3.2. Survey analysis	23
4. Findings.....	27
4.1. Barriers and drivers to demand-side flexibility	27
4.2. Influencing variables to social acceptability of DSF	37
4.3. Acceptability of manual shifting in France	47
4.4. Main findings	50
5. Discussion	51
5.1. Implications of the study.....	51
5.2. Limitations of the study	52
5.3. Suggestions for further work	52
6. Conclusion	54
List of figures.....	55
List of tables	56
References	57
Appendices.....	61
Appendix 1. List of articles selected in the structured literature review	61
Appendix 2. Explanation of the variables	62
Appendix 3. Descriptive statistics of respondents (IPSOS_2025).....	63
Appendix 4. Variables effect on acceptability of midday hours manual shifting	64
Appendix 5. Variables effect on acceptability of late evening manual shifting	65

Abbreviations

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (Environmental and Energy Management Agency)
DLC	Direct Load Control
DSF	Demand-Side Flexibility
EV	Electric vehicle
HEMS	Home Energy Management System
RTE	Réseau Transport Electricité (Electricity Transport Network)

1. Introduction

1.1. Background

Ensuring the balance between electricity supply and demand is a fundamental requirement for the stability of the power grid. This balance necessitates the continuous production of sufficient electricity to meet consumption needs. From an economic standpoint, the goal is to optimize electricity production costs by leveraging the most cost-effective generation methods. Additionally, there is an environmental imperative to maximize the use of carbon-free energy sources (Parrish et al., 2020; RTE, 2024a).

With the increasing penetration of renewable sources, that are less predictable and controllable, the network needs more flexibility. Flexibility is “the ability of a means of production, consumption, or storage to increase or decrease its injection or withdrawal from the grid” (translated from (RTE et al., 2024, p.13)). In concrete terms, to ensure production-consumption equilibrium at any time, utility usually activates controllable thermal power stations (RTE, 2024b). Demand-side flexibility (DSF) is an attractive alternative to these solutions that are often costly or consume fossil fuels (Parrish et al., 2020). While DSF is quite developed for large consumers such as industry and commerce, the residential potential still needs to be improved (RTE et al., 2024).

In 2023, residential electricity consumption accounted for 39% of final electricity consumption in France (EDF, 2025a). This consumption is responsible for seasonal peaks during cold spells and daily peaks at the beginning and end of the day. The objective of DSF is to eliminate or reduce consumption during peak periods, especially in winter, and introduce flexibility into daily life, so that consumption can be adjusted and shifted where possible. Residential consumers would thus preferably be consuming electricity when renewable and nuclear power is most abundant and prices are low: at night and increasingly during midday hours (Parrish et al., 2020; RTE et al., 2024).

DSF encompasses very different actions from the users as it can be made possible through *Direct Load Control* (DLC), e.g. by giving the control to utility or an external aggregator, or through *manual* actions to shift usages like laundry to off-peak hours (RTE et al., 2024). Also, households’ electricity consumption is related to different uses such as washing (laundry, tumble dryers, dishwashers), showering, cooking, heating water and spaces, electric vehicle charging... Previous classifications of flexibility actions have mainly been done from a grid perspective but lack understanding of users’ barriers.

Many public organisations have taken up the issue of DSF: electricity network operators such as EDF and RTE are studying these issues closely, the French Environmental Agency ADEME (2024) is interested in this subject, as are the Ministry of the Economy (Campana et al., 2020) and the Senate (Delahaye, 2024). DSF is often approached from a technical perspective, with numerous research publications focusing on control algorithms (Golmohamadi, 2022; Ha, 2007; Lucas, 2021). While the technological and technical components of demand response cannot be overlooked, DSF relies primarily on consumers. Therefore, it is important to study the social conditions for developing DSF.

1.2. Literature review: highlighting research gaps

1.2.1. *Growing interest for demand-side flexibility from a grid and technological perspective*

The issue of demand management first arose in the 1980s during the oil crisis (Gellings, 1985). More specifically, the flexibility of the electricity system was seen as necessary for balancing the grid. Many public French organisations have taken up the issue of Demand-side flexibility (DSF): electricity network operators such as EDF and RTE are studying these issues closely, the French Agency of Energy Management and Environment (ADEME) (2024) is interested in this subject, as are the Ministry of the Economy (Campana et al., 2020) and the Senate (Delahaye, 2024).

Demand-side flexibility encompasses a great variety of actions. Therefore, reflections on how to classify and distinguish different types of flexibility are being conducted by public organisations and scholars: different timeframes for flexibility requirements (RTE, 2024b, 2024a; RTE et al., 2024), methods of consumption management (RTE, 2024b; RTE et al., 2024), explicit and implicit demand response (EDF, 2025b; RTE et al., 2024). Potential sources of flexibility are also expressed according to different uses by RTE (2024a).

Various classifications of these uses have been presented in the literature: according to the possibility of interrupting or delaying electrical appliances (Mishra and Singh, 2025), according to their level of flexibility (Smale et al., 2017) or based on the possibility of programming them using a thermostat (Golmohamadi, 2022). Fabianek et al. (2025) introduce a multi-criteria assessment framework, specifically for Direct Load Control in residential buildings. Libertson (2022) presents a framework of analysis of DSF by end-users, introducing concepts like *flexibility capitals*, thus presenting flexibility as a result from socio-temporal facilitation and resources. Thus, frameworks to classify actions from users have been introduced but are considered either too narrow (focus on one type of appliance or flexibility) or too user-centric (need to consider the impact on the grid as well) to be used for in forward-looking studies on the electric network. The theoretical framework I designed for this study is meant to answer this issue.

Technical and technological requirements to DSF development have been studied (Ha, 2007; Lucas, 2021). DSF is often approached from a technical perspective, with numerous research publications focusing on control algorithms (Golmohamadi, 2022; Ha, 2007; Lucas, 2021).

While the technological dimension of DSF can't be ignored, demand-side flexibility in the residential sector relies on the building's occupants.

1.2.2. *Social acceptability of demand-side flexibility*

In Europe, several research have been conducted on the question of acceptability and user's behaviour.

Firstly, several research teams are studying residents' practices in relation to energy consumption in general.

In his thesis, Subrémon (2009) examines social practices relating to energy in the domestic sphere, using an ethnographic approach involving immersion in three families, including one French family, followed by a field study involving 10 French families in particular. Roudil et al. (2015) present the parameters that structure domestic energy consumption: economic constraints, comfort standards and the relationship with the material and technical environment. Three modes of consumption

change linked to demand management imperatives are identified according to changes in habits and environmental values. Zélem (2018) analyses the social practices in the buildings: presenting behaviour as part of a complex socio-technical system, questioning the norm of comfort, introducing four users profiles and discussing incentives for the energy transition. Brisepierre (2015) studies the heating behaviour of French households in response to political, legal and technical requirements to maintain a heating temperature of 19°C.

Consumer behaviour has also been studied in relation to demand flexibility. Two smart grid pilot programmes in the southern Netherlands were analysed through the lens of practice theory (Smale et al., 2017). Lavin & Julienne (2025) analysed the behaviour of Irish households during peak consumption periods. Chatzouli et al. (2025) studied electric vehicle charging behaviour in Denmark, identifying three typical profiles. Several studies address flexibility from the perspective of optimisation algorithms or Home Energy Management System (HEMS) programming while including user preferences (Carloganu, 2016; Durillon, 2019; Fanitabasi and Pournaras, 2020).

More specifically, the factors influencing social acceptability of electricity demand flexibility in the residential sector have been studied in Europe. The approaches vary depending on the publication.

Firstly, several studies address the subject from an economic perspective, for example by comparing different types of contracts (Gleue et al., 2021) or assessing the willingness to accept of consumers (Wen et al., 2025). The behavioural response to dynamic prices with feedback was also studied in a Swedish case study (Öhrlund et al., 2019).

Furthermore, most studies focus on the acceptability of flexibility for one or more specific uses. The actual use and long-term influence of a Home Energy Management System (HEMS) was studied in a case study of a Swedish neighbourhood (Hagejård et al., 2023). The analysis of the results of surveys and interviews conducted with participants was carried out through the lens of practice theory. The acceptance of HEMS is also studied in Austria by Pfeiffer et al. (2021) for domestic hot water and heating uses. They identify five user profiles according to their acceptability. Bender et al. (2024) are also interested in flexibility for residential heating. Based on an online survey, the willingness to participate in a regional flexibility market is analysed. In Luxembourg, researchers studied the influence of energy culture (basic understanding of energy use and its link to everyday appliances) and environmental values on the acceptance of direct load control for heating and electric vehicle charging (Andolfi et al., 2024). Kubli et al. (2018) studied contract preferences (level of flexibility varying according to user instructions) in three situations: owners of solar panels with storage capacity, electric vehicles or heat pumps.

Also, more general papers addressing multiple uses or *demand response* programs have been identified. A survey was used to analyse the factors influencing willingness to participate in a demand response programme, perceptions of smart technologies, and barriers to changing habits (Tomat et al., 2023). Parrish et al. (2020) conducted a systematic literature review to identify the motivations, drivers and barriers to demand flexibility in Europe (including the UK), North America, Australia and New Zealand. Their findings highlight the importance of financial and environmental benefits, risk control and perception, and complexity of implementation. The role of risk perception is also highlighted in a study of 10 German households (Barthe et al., 2015). In the United Kingdom, Li et al. (2020) looked at households' willingness to shift their daily activities such as cooking, washing, heating, etc., without considering the tariff signals that enable this shift. The different uses were classified according to their flexibility potential, with washing practices considered the most promising (Smale et al., 2017). Socio-demographic factors have been linked to different motivations for participating in demand response programmes among Finns (Sridhar et al., 2023a, 2023b).

However, very few studies focus on France. In their article, O'Reilly et al. (2024) first analysed the results of some twenty European studies on flexibility in order to obtain a percentage of participation in consumption shifting according to usage. Secondly, the responses to the ECHOES H2020 survey concerning the theoretical authorisation of a third party to switch non-essential electrical appliances on or off in exchange for a certain price were translated into a percentage of participation in shifting consumption by country, including France. By cross-referencing the data from the first analysis with participation by country, the study presents participation percentages by country and by usage. However, the explanatory variables for this participation are not analysed. In their PhD thesis, Shahid (2022) conducted a behavioural science experiment with 175 households to understand their response to nudge encouraging them to shed or shift their consumption. The variables that could influence the response to nudges (socio-demographic factors, household size, presence at home etc.) were only used to check for the similarity of the control and treatment groups and not as explaining the response to nudges. D'Ettoire et al. (2022) have also worked with several European countries, including France. They conducted a survey to understand drivers and barriers to Direct Load Control.

A survey of residents of the island of Mayotte was used to analyse user preferences regarding price signals, direct control by a third party of certain electrical appliances, and their motivations for choosing flexibility programmes (Schöne et al., 2022). In Metropolitan France, Caron and Durand-Daubin (2016) present the results of a load shedding experiment using a remote heating control device installed in nearly 500 households. Analysis of participants' responses enabled them to identify the main motivations for participating in the project as well as the reasons given for exemptions from load shedding requests. They proposed eight participant profiles for the project.

Some research are also currently being conducted. Khubashvili (n.d.) is currently working on an agent-based model to assess the flexibility potential of households in diverse situations.

1.2.3. Literature review summary: Research gaps

As discussed above, research on DSF has already been conducted in Europe, either to present the general issues involved or to focus on acceptability. However, most of the research on acceptability has focused on few uses at a time, such as heating and hot water production (Bender et al., 2024; Pfeiffer et al., 2021), EV charging (Andolfi et al., 2024) and washing machine (D'Ettoire et al., 2022), or a single type of flexibility like HEMS (Hagejård et al., 2023; Pfeiffer et al., 2021) or DLC (D'Ettoire et al., 2022). The aim here is to aggregate these results while considering the specific characteristics of these different types of action.

Moreover, although the literature on acceptability in Europe is extensive, few studies including France (the geographical scope of this study) have been identified. According to the results of D'Ettoire et al. (2022), there are differences among European countries when looking at obstacles and drivers of flexibility. For instance, the ease of use is a driver for 31% of Spanish households, regarding DLC compared to 19% in France. Therefore, a focus on France situation is needed and one can't translate directly the results from European countries as such.

1.3. Aim

The aim of the study is to identify and understand the factors and mechanisms that determine the acceptability and development of demand-side flexibility (DSF) among French households, in order to inform strategies for increasing DSF adoption in the residential sector and facilitate modelling in future studies.

To guide the investigation, the following three research questions are posed:

Q1. What are the social barriers and drivers that hinder or foster demand-side flexibility among French households?

Q2. Which variables influence the acceptability of various types of demand-side flexibility based on household characteristics (socio-demographic, organisation, values)?

Q3. How are different categories of flexibility actions perceived and accepted, and how do these perceptions vary according to the identified influencing variables?

1.4. Study context

This study has been conducted during an internship at RTE, the French electricity transmission system operator. RTE's primary mission is to ensure the balance between supply and demand in the system by maintaining and dimensioning the extra-high voltage electricity network. In order to anticipate network requirements and inform public debate, RTE carries out forward-looking studies (*Bilan prévisionnel, Futures énergétiques,...*).

My work is therefore part of a more in-depth study on the future of the French electricity network. To be more specific, my work provides insights into the potential for electricity flexibility in the residential sector.

That's why the research focuses on both the impact on the grid and social acceptability from the user's perspective. Also, since the households' characteristics that influence social acceptability will form part of a broader model describing the future electricity network, the term '*variable*' is used to refer to them.

1.5. Structure

The thesis is structured as follows: part 2 presents the methodology of the research. Part 3 introduces the key concepts and their definitions. The theoretical framework that guides my analysis is also designed in this part. The findings are presented in part 4. Finally, discussion on the limitations and implications of the study is conducted in part 5.

2. Theoretical framework

2.1. Key concepts

2.1.1. Demand-side flexibility actions

Flexibility is “the ability of a means of production, consumption, or storage to increase or decrease its injection or withdrawal from the grid” (translated from (RTE et al., 2024, p.13)). The system flexibility is becoming of great interest with the increasing share of renewable sources in the electric mix. To ensure the network reliability, network operators may rely on the production-side by launching controllable power stations, usually consuming fossil-fuel and expensive (RTE et al., 2024).

Instead of solely counting on production, utility can encourage demand-side flexibility. From the previous definition, it's a focus on the ability of means of consumption to be flexible. In their definition, RTE (2022) mentions that flexible uses refer to load shifting or load shedding.

Definition 1 – Demand-side flexibility

Ability of a means of consumption to increase or decrease its withdrawal from the grid. It concerns multiple usages that can contribute to load shifting, modulation or load shedding.

First, load shedding, load shifting and modulation, as understood from their impact on the grid, are allowed by curtailable appliances, shiftable/deferrable and adjustable appliances, respectively. Using the definitions from Ha (2007) and RTE et al. (2024), the following definitions are introduced.

Definition 2 – Types of flexibility for a means of consumption

An electric appliance use can be:

- **Adjustable (modulation)**: the power consumption can be reduced during a limited time without a stopping completely. For example, the heating setpoint temperature can be lowered for a period of time, which results in reduced power consumption without stopping completely.
- **Potential for load shedding / curtailable**: the consumption can be stopped for some amount of time. For instance, heating can be turned off for a few minutes, while a washing machine cannot be stopped during a cycle.
- **Deferrable/Shiftable**: it can be shifted over time. In concrete terms, the service can be done before or after the usual use. For instance, a dishwasher can be used at night instead of during the day.

To illustrate these definitions, their impact on the load curve is presented (**Fig.1**).

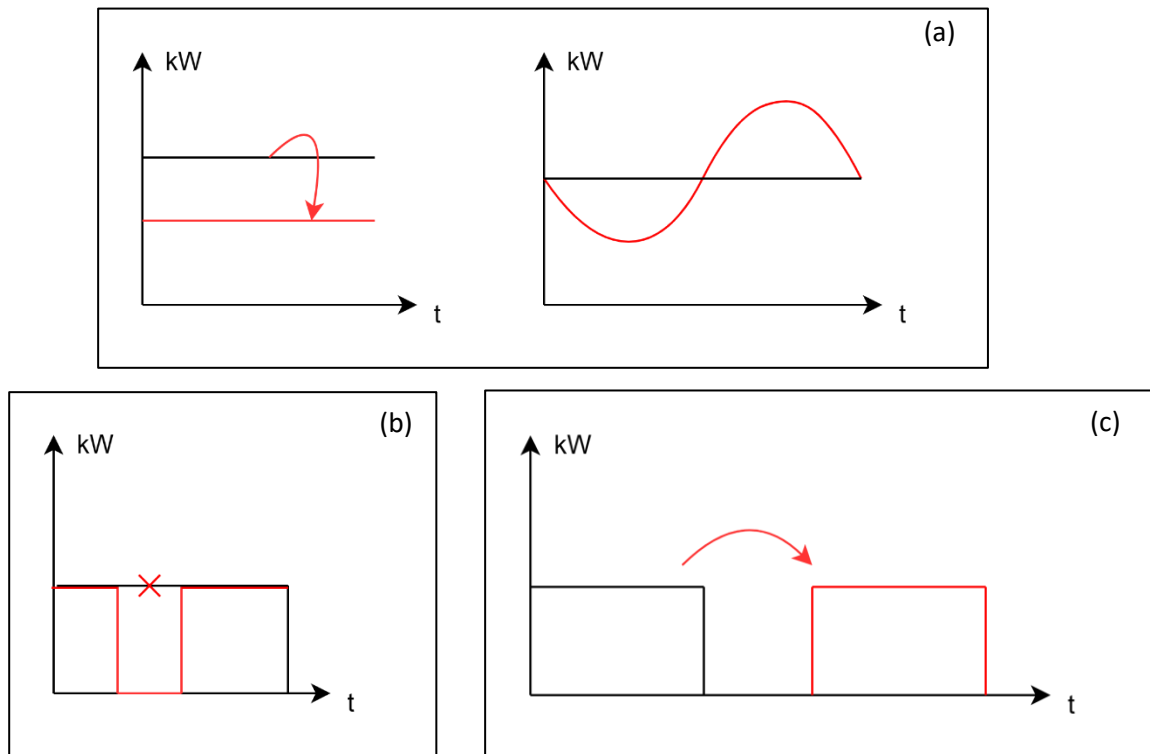


Figure 1. Load curve change from (a) adjustable (b) curtailable and (c) deferrable appliances. In black the usual energy consumption and in red the change allowed by each type of flexibility (made by author).

Then, load shedding and modulation are regulated in France by electricity market rules. In the market rules for the NEBCO mechanism (RTE, 2025), load shedding is defined as follows: "In accordance with Article L271-1 of the Energy Code, an action aimed at temporarily reducing, upon a one-off request sent to one or more end consumers by a load shedding operator or an electricity supplier, the actual level of electricity withdrawal on the RPT or RPD of one or more Withdrawal Sites, compared to a forecast consumption program or estimated consumption." The end consumers here can be big consumers such as industrials or offices or an aggregation of multiple ones including households.

Article L271-2 of the Energy Code specifies the terms and conditions for load reduction for end consumers: "[They] have the option of monetizing each of their electricity consumption reductions either directly with their supplier as part of a load reduction offer that is inseparable from the supply, or on the energy markets or through the adjustment mechanism referred to in Article L. 321-10 via a demand response aggregator offering a service that is separate from a supply offer." (Articles L271-1 à L271-4 - Légifrance, 2025).

Various concepts and actions are related to DSF. The term demand response is regularly used in English literature to refer to demand-side flexibility. It is defined as "the changes in consumer consumption patterns in response to specific signals" (Sridhar et al., 2023, p.1).

Usually, scholars introduce two types of demand response (D'Etorre et al., 2022; Sridhar et al., 2023a):

- Implicit demand response: consumer's response to price signals.
- Explicit demand response: a third party (aggregator or supplier) control some appliances and reward the consumer with money. It is often referred to as Direct Load Control (DLC).

However, implicit demand response could also work with "specific signals" (Sridhar et al., 2023a) that are not price signals. For instance, in the Ero 2.0 pilot in Sweden, participants were to respond to signals

based on a personal threshold based on selected energy sources availability (Hagejård et al., 2023). The price signals received by the user can also take different forms: curve price received a day ahead with red and green periods to consume electricity (Christensen et al., 2020).

As demand response can be implicit or explicit, it can also be seen as manual or automated. Implicit demand response is usually manual, while the explicit one is automated. The level of automation can vary depending on the appliances and technological means.

The main potentially flexible uses in the residential sector have been identified. First, electric vehicle charging is presented as a real lever for the years to come (EDF, 2025b; RTE, 2024b, 2024a, 2022). The automatic control of domestic hot water using peak/off-peak signals, which has been in place since the 1980s, is also a source of flexibility (Campana et al., 2020; RTE, 2024a, 2024b, 2022; RTE et al., 2024). Electric heating, particularly via heat pumps, is a significant source of flexibility (ADEME, 2024; Campana et al., 2020; EDF, 2025b; RTE, 2022; RTE et al., 2024). Finally, white goods (washing machines, tumble dryers, dishwashers, etc.) are also mentioned by RTE et al. (2024) and Campana et al. (2020).

Finally, from the user’s perspective, several actions can be implemented to contribute to demand-side flexibility. First, households can rely on *smart technologies* to allow them a better control of their consumption by delaying washing machines (D’Ettorre et al., 2022) or controlling room temperatures on a phone app (RTE et al., 2024). Direct Load Control allows a third-party to control some appliances. An example in France is the aggregator *Voltagis* that switches off electric heaters for small amount of time during high demand-period (Bivas, 2023). Moreover, manual shifting of usual practices involving white goods is another way to contribute to flexibility for users (Friis and Haunstrup Christensen, 2016; RTE et al., 2024).

To summarize this part, the key concepts explained above are represented in **Figure 2** with real-life examples when applied to residential demand-side flexibility.

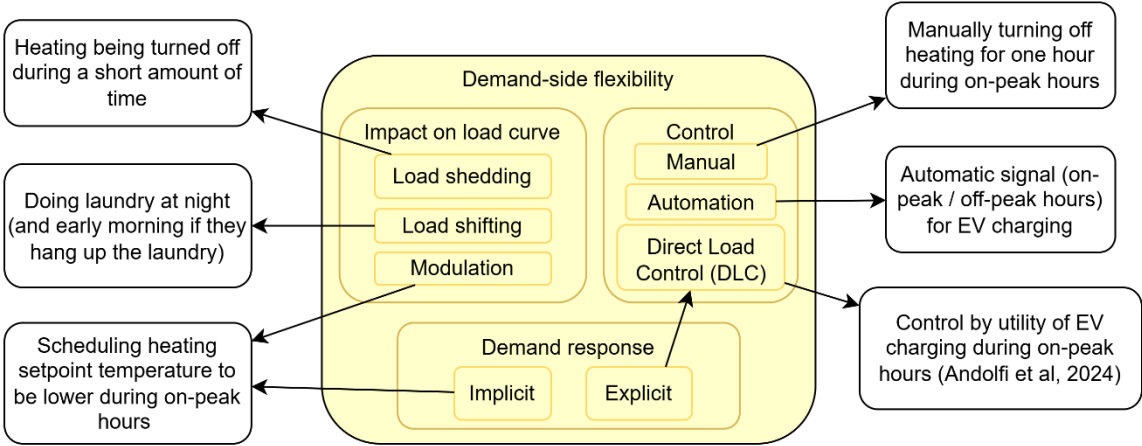


Figure 2. Diagram explaining the concepts surrounding demand-side flexibility (yellow) using real-life examples (white) – made by author

2.1.2. *Social acceptability: a debated concept*

I will focus on the social acceptability of demand-side flexibility. Social acceptability is a debated concept among scholars, since it has been introduced and mostly used by extractive industries (Baba and Raufflet, 2015; Gendron et al., 2024). A key component of social acceptability is the comparison between alternatives and a *statu quo*. Also, commonly used definitions refer to the acceptance of a given project or decision (Alcantara et al., 2023; Baba and Raufflet, 2015). In his thesis, Durillon (2019) uses the definition from Véronique Yelle, that refers to the acceptance of a **practice** and not necessarily a project related to a company. This is the definition I will use in my work (**Definition 3**).

Definition 3 – Social acceptability – translated definition from Durillon (2019)

“Social acceptability is the aggregation of individual judgements regarding the acceptance (or rejection) of a practice or condition, whereby individuals compare it with possible alternatives to determine its desirability. It is conveyed by politically significant groups within society who share the same judgement regarding this practice.”

2.1.3. *Theory of social practices as a lens of analysis*

According to Bovay et al. (1987, quoted by Caron and Durand-Daubin (2016)), the study of domestic energy consumption must “place energy consumptions behaviours and attitudes within the context of everyday activities”. This broader perspective makes it possible to understand the multiple reasons why particular individuals consume energy in specific ways. As such, this study adopts the theory of social practices as a lens of analysis, following a tradition widely used in research on domestic resource use (Hagejård et al., 2023).

While different conceptualizations exist, I will use the definition (**Definition 4**) from Shove et al. (2012).

Definition 4 – Practices – definition from Shove (2003) and Shove et al. (2012)

Practices consist of active integrations of *material* (things, technologies, infrastructures, hardware, body itself), *competence* (skills, know-how techniques) and *meaning* (symbolic meanings, ideas and aspirations).

Unlike approaches focusing solely on individual attitudes or technological factors, the theory of social practices centres attention on the socially shared routines and conventions that shape daily life. Individuals' actions are thus seen as the product not just of personal choice, but of established social conventions and the situational constraints of everyday life (Shove et al., 2012).

A particular strength of social practice theory is its attention to the temporal organisation and synchronisation of activities. Peaks in domestic electricity demand often occur not because of random decision-making, but because large numbers of people perform similar or different energy-intensive activities at overlapping times, such as cooking, laundry, or entertainment, reflecting inter-related social rhythms and routines. By taking social practices as a unit of analysis, this study examines not only what people do, but also the difficulties to change these patterns due to synchronisation with other practices (Shove and Cass, n.d.).

Research utilising time-use data and sequence analysis demonstrates that demand peaks frequently arise from these temporal synchronisations and can vary between population groups and across the week. Understanding these fine-grained rhythms is therefore helpful for understanding the origins of peak demand and identifying opportunities for demand-side flexibility (Shove and Cass, n.d.).

The concepts of ‘hot spot’ and ‘cold spot’ theorized by Southerton (2003) give insights on the integration of DSF solutions into everyday life of households. On one hand, ‘peak periods’ of consumption usually coincide with ‘hot spots’: predictable periods of the day that precede institutionally timed events (school, work, meals). These periods are often intense in the number of activities performed within a limited time and thus come with multitasking (Friis and Haunstrup Christensen, 2016). These tight schedules, especially in the morning, can make it difficult to shift practices or to add new tasks in an already constrained period (Friis and Haunstrup Christensen, 2016; Tomat et al., 2023). On the other hand, ‘cold spots’ are associated with quality and family time, that households may refuse to disturb. For instance, doing the laundry overnight implies to hang clothes in the morning which is considered inconvenient, as it disturbs the family togetherness over breakfast (Friis and Haunstrup Christensen, 2016).

Therefore, the theory of practices provides insights into DSF. On one hand, some practices are inherently more flexible than others, explaining why certain uses (like laundry or dishwashing) may be easier to reschedule than more tightly anchored activities (such as meals). On the other hand, individuals differ in their flexibility “depending on the range and sequence of practices in which they are involved” (Shove and Cass, n.d., p.9).

In this study, since this work is based on users’ perspective, I have thus decided to work with practices instead of appliances. As mentioned by Hagejård et al. (2023), “the use of a specific appliance is not a practice in itself but view such activities as part of wider practices. For instance, using the washing machine and tumble dryer are part of the practice of doing laundry.” The acceptability of flexibility corresponds to the acceptability of a change in a domestic practice for its flexible version compared to the statu quo version. For instance, doing laundry becomes doing laundry at off-peak times or doing laundry using a schedulable washing machine. Flexibility actions are the actions that contribute to transforming the domestic practices (**Fig. 2**).

2.2. Framing demand-side flexibility from user’s perspective

As discussed in the previous section, DSF includes a wide range of actions designed to make practices more flexible (see **Fig. 2**). Therefore, analysing the acceptability of DSF requires evaluating each of these individual actions. To better understand the barriers to, or variables influencing, the acceptability of DSF, I have developed a theoretical analytical framework that categorises these actions according to the aspects that affect their acceptance.

It is also important to note that this study aims to generate results relevant to the perspective of the electricity grid. Consequently, the aspects used to categorize the various flexibility actions must both influence user acceptability and be suitable for modelling the future electricity grid.

2.2.1. *First steps to classify residential electrical uses – technical considerations*

Non-flexible practices

First, some electrical uses/practices in the home are not flexible. Cooking and entertainment activities for instance are considered unflexible by many scholars (Durillon, 2019; Golmohamadi et al., 2024; Mishra and Singh, 2025; Parrish et al., 2020). Cooking practices are determined by institutional rhythms (timing of after-school and work) but also cultural conventions regarding a ‘proper time to eat dinner’, making them more difficult to shift (Friis and Haunstrup Christensen, 2016). This can be verified empirically with respondents who believe that they can’t change their cooking habits and meals times

(Hagejård et al., 2023). The importance of shared meals in the family, and the interconnexion with other practices when having children (Öhrlund et al., 2019) led me to consider cooking and eating practices as non-flexible. Finally, I will consider lighting as non-flexible in France. In fact, Golmohamadi et al. (2024) is the only scholar to present lighting as curtailable in North Europe through dimmable lighting. As dimmable lighting is not that common in French houses, I thus follow the classification as non-flexible from other scholars (Durillon, 2019; Mishra and Singh, 2025; Parrish et al., 2020).

Technical flexibility potential of residential electricity uses

Then, a first step to classify the different uses was to get a technical understanding of their flexibility potential.

For the appliances, their thermal storage capacity is often put forward as a distinguishing factor. For residential appliances, thermal storage capacity is frequently identified as a key factor in determining flexibility. Parrish et al. (2020) distinguish between appliances that rely on thermal inertia, such as space heating systems and hot water tanks, and those for which electricity use and the delivery of the energy service are temporally decoupled, notably so-called *wet appliances* (commonly referred to as *white goods* in France (RTE et al., 2024)). Building on this distinction, Golmohamadi et al. (2024) propose a typology of controllable electrical loads that separates thermostatically controllable appliances (TCAs) whose consumption follows thermal dynamics, from controllable non-thermal appliances (CNTAs), whose flexibility is not constrained by thermal processes. For these latter appliances, flexibility may take the form of deferral, whereby the activity is shifted in time without altering total energy use, or curtailment, where power demand can be reduced or increased without delaying the remaining consumption. From this perspective, assessing an appliance's ability to store energy appears as a fundamental step in evaluating its flexibility potential.

The same parameters appear in Ha (2007)'s work, notably the possibility of shifting or modulating the consumption of an appliance. They introduce the concept of degrees of freedom to distinguish various services. Four types of degrees of freedom are identified as follow:

- Deferrable: the service can be postponed
- Interruptible: the energy flow may be interrupted and started again later
- Adjustable: the energy flow can be adjusted but without complete interruption
- Storable/Accumulable: the energy can be stored for later use

These technical considerations refer us back to the terminology presented in Definition 2, which introduces the three categories: Deferrable/Shiftable, Adjustable, Potential for load shedding / curtailable (RTE et al., 2024).

Based on the previous discussion, these three categories together with the possibility to store energy are considered. I propose the following classification of flexible residential uses depending on the load change they allow (**Table 1**). To do so, I use the proposed distinctions made by Ha (2007) and the previous definitions.

These technical considerations (**Table 1**) translate changes in user practices into a concrete effect on the consumption curve. It helps to understand the flexibility potential of different practices.

Table 1. Classification of electric uses depending on the load change and highlighting non-flexible uses (made by author)

Use / Service	Deferrable	Storable	Adjustable	Load shedding potential	Nonflexible
Heating / AC		X	X	X	
Hot water production	X	X	X	X	
Wet goods / washing	X				
EV charging	X	X	X	X	
Entertainment (TV, computer, gaming...)					Instant use
Lighting					Instant use
Phone, computer charging					Too small consumption to be relevant
Cooking practices					Instant use

2.2.2. Dimensions to classify residential electricity uses

Temporality

The technical considerations introduce temporality as a determining feature from a network perspective. According to (RTE et al., 2024), the demand-side flexibility can be regular / structural or dynamic. A distinction is to be made between a dynamic flexibility on special days (peak days, few times a year) and dynamic flexibility everyday (dynamic pricing).

Regular flexibility means that there are fixed timeslots when consumption is encouraged. It corresponds to the system of “On-peak/Off-peak hours” or to electricity tariffs that distinguish weekdays and weekend. These fixed timeslots can still vary depending on the season (RTE et al., 2024).

Dynamic flexibility is a less predictable form of flexibility for the users. The first one is a dynamic one, everyday, which corresponds to real-time pricing, and allows to answer the grid’s needs as close as possible to real time. The second one, on specific days, means that a few days (a month or a year depending on the contract) are selected as peak days, thus encouraging users not to consume on these days. This is the principle of some tariffs in France (like Tempo tariff) that assign a colour to each day: white, blue and red. On red days, electricity is really expensive during on-peak hours to encourage people to shift and reduce their consumption (RTE et al., 2024).

The timing of flexibility actions must also be considered from the user's perspective. In fact, the relationship between practices and the temporality of everyday life is detailed in the theory of practices (Friis and Haunstrup Christensen, 2016; Schöne et al., 2022) and must be accounted for in this framework. In their framework of analysis, Libertson (2022) includes the temporality issue under the concept of social synchronization among households.

Thus, temporality of flexibility actions can influence user acceptability. For instance, regular flexibility can necessitate long-term changes to habits, while dynamic flexibility on a few peak days only requires households to make temporary adjustments.

Level of automation and third-party control

The second aspect that is considered in the framework is the *level of automation*. RTE et al. (2024) present different level of control over the appliances (**Table 2**): manual control over appliance, centralized manual control over one use, automated control of appliance based on signals, global

automated control (HEMS). The centralized manual control over one use implies the ability to control it remotely.

This criterion is important both from a network perspective and for the consumer. Indeed, the reliability of flexibility sources varies depending on whether they are based on manual action by the consumer or automated by an aggregator or signal (RTE, 2022).

Furthermore, the actions required of the consumer differ depending on the level of automation. On one hand, manually controlled flexibility also comes with difficulties for users. In fact, learning eco-friendly habits to become more flexible comes with a cost in terms of time, skills and mental effort that is too high for some people to bear (RTE, 2022). On the other hand, according to a survey from 2018 (CREDOC), 20% of French households are willing to accept third-party control over their appliances, showing the impact of automation on the willingness to be flexible (RTE, 2022). In their framework, Libertson (2022) includes both the controller of flexibility economisation (self or other) and the type of flexibility source (technological or social) as a criterion.

Therefore, the presence or absence of a third party is retained as a criterion in our analytical framework. To this end, a fifth level of automation has been added to the RTE classification (presented in **Table 2**): Control by a third-party (DLC). This level corresponds to a situation where the utility or an aggregator can control some appliances, usually for one specific use.

Table 2. Level of control over appliances (RTE et al., 2024)

Level of automation	Explanation
Manual control over one appliance	“The occupant indicates the desired operating mode (e.g. Eco mode) on the equipment (or on an added system) and can also set a schedule for each room. This is the most common control mode (used in two-thirds of electric heating control systems) but is limited due to poor ergonomics, the lack of automatic tariff signal updates and the absence of overall optimisation, particularly regarding power demand.”
Centralised manual control, single use	“With a central wall-mounted control panel or a mobile app connected to the equipment (original or added systems), control is more ergonomic and easier. Occupants can manually programme a type of equipment, such as electric heating, but within the limits of non-automated control. With a connected solution, they do not need to be in their home to control it.”
Automatic appliance control through a signal	“Triggered automatically by the meter signal, the hot water tank or charging station is activated during off-peak hours thanks to the contactors often found in the electrical panel. The control system is typically compatible with equipment that supports ON-OFF control and whose consumption can be shifted (electric vehicle charging and hot water tanks).”
Centralised automatic control, global	“HEMS (Home Energy Management System) automates the programming of equipment according to the occupant's preferences and based on several parameters (tariffs, weather, presence/absence, etc.). The occupant is thus assisted by an intelligent system that controls the entire home to optimise electricity bills (energy and power) and comfort. The occupant can take back control of the automatic control system at any time.”

2.2.3. Framework of analysis

The final analytical framework therefore corresponds to the classification of different uses in a two-entry table, according to the two aspects highlighted above: temporality and level of automation (Table 3).

Some intersections between temporality and automation have been omitted. For instance, it is considered impossible to achieve dynamic flexibility on a daily basis manually. This is because it would require households to monitor price or consumption signals in real time and adapt their practices accordingly. Automation is more adequate to respond to time-varying pricing (Parrish et al., 2020). Automatic signals for dynamic flexibility on peak days are also disregarded, as a dynamic signal everyday would include distinction from one day to another. Third-party control does not include regular flexibility, since this type of DLC is valued on other favourable electricity tariffs. Finally, HEMS consider both preferences from users (indoor temperature, home occupancy...) and grid needs. These two aspects can be both regular and dynamic and we thus consider the temporality as not being a factor for HEMS acceptability.

Table 3. Categories of DSF actions based on their temporality and their level of automation (made by author)

		Temporality			Not flexible	
		Regular flexibility	Dynamic flexibility – few peak days	Dynamic flexibility everyday		
Level of automation	Manual	Manual control of the appliance (Eco mode, turning on dishwasher...)	1. Hot water production Heating/AC EV charging Washing	2. Hot water production Heating/AC EV charging Washing	/	Cooking Entertainment activities Lighting
		Centralized manual control over one use (control panel for heating, possibility to automatically delay laundry...)	3. Hot water production Heating/AC EV charging Washing	4. Hot water production Heating/AC EV charging Washing	/	
	Automated	Automated control of appliance through signal (automatic signal)	5. Hot water production EV charging	/	6. Hot water production EV charging	
		Control by a third-party (DLC) (utility or aggregator can control some appliances, turns off heating for a few minutes...)	/	7. Hot water production Heating/AC	8. Hot water production Heating/AC EV charging	
		Global automated control (HEMS)	9. Hot water production Heating/AC EV charging			

This section lays the groundwork for the acceptability analysis. In the following sections, I will refer to these nine categories of flexibility actions (**Table 3**) to adapt the results of the literature review and survey to the specific characteristics of these categories. For example, the barriers and drivers for households will be discussed in general terms, and then the nuances between one category of actions and another will be identified.

3. Methodology

The overall methodology can be summarised as shown in **Figure 3**. The different steps are detailed in this chapter.

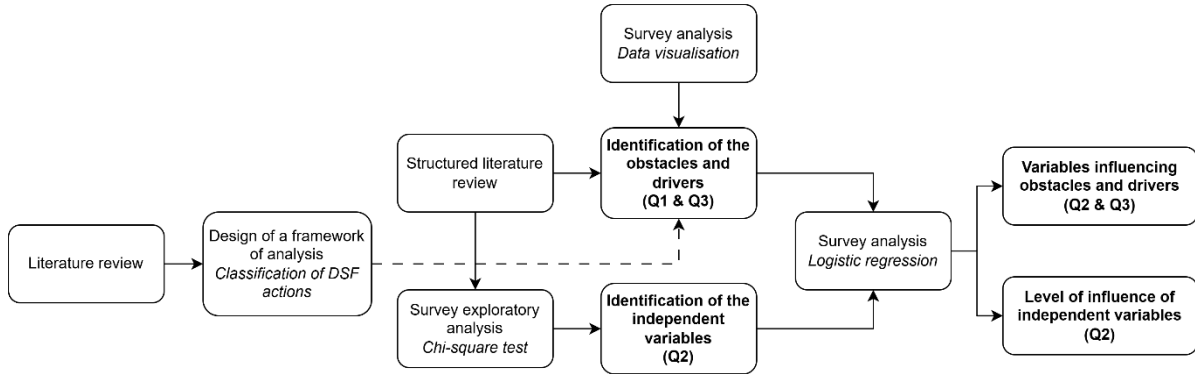


Figure 3. Methodological process to identify and assess the influencing factors of DSF acceptability

The design of the framework of analysis has been described in part 2 and was based on a literature review.

3.1. Structured literature review

To identify relevant variables influencing social acceptability of DSF as well as motivations and barriers for users, a structured literature review was conducted. As explained by Parrish et al. (2020), a systematic literature review aims to identify a comprehensive selection of reports detailing variables influencing social acceptability of households DSF. However, since a systematic literature review intends to be exhaustive, its proper implementation requires a great amount of resources and time, up to 12-24 months (Villar, n.d.). Instead of a systematic literature review, a structured literature review was conducted. I followed the same steps as for a systematic literature review, but only the first 200 articles of each source were screened (**Fig. 4**).

The structured literature review was conducted on Scopus and Web of Science using key words corresponding to specific themes as described in **Table 4**. A preliminary literature review was conducted with a small sample of articles to identify the key words. After compiling a list of potential keywords, they were tested to check how sensitive the search was depending on the chosen words. The final selection is presented in **Table 4**.

Table 4. Key words search and their associated theme

Themes	Key words
DSF	demand-side flexibility, demand flexibility, demand response, demand-side response, Direct Load Control
Acceptability	Acceptability, acceptance, willingness, survey, predictor
Residential sector	Residential, household, home

The following research queries were used (**Table 5**).

Table 5. Search queries for Web of Science and Scopus

Source	Query
Web of Science	(TS=("demand-side flexibility") OR TS=("demand flexibility") OR TS=("demand response") OR TS=("demand-side response") OR TS=("Direct Load Control")) AND (TS=("residential") OR TS=(household) OR TS=(home)) AND (TS=(acceptability) OR TS=(acceptance) OR TS=(willingness) OR TS=(survey) OR TS=(predictor))
Scopus	(TITLE-ABS-KEY ("demand-side flexibility") OR TITLE-ABS-KEY ("demand flexibility") OR TITLE-ABS-KEY ("demand response") OR TITLE-ABS-KEY ("demand-side response") OR TITLE-ABS-KEY ("Direct Load Control")) AND (TITLE-ABS-KEY ("residential") OR TITLE-ABS-KEY (household) OR TITLE-ABS-KEY (home)) AND (TITLE-ABS-KEY (acceptability) OR TITLE-ABS-KEY (acceptance) OR TITLE-ABS-KEY (willingness) OR TITLE-ABS-KEY (survey) OR TITLE-ABS-KEY (predictor))

Since the study focuses on the French case, French-language literature was also sought. Previous publications from RTE were used, and research conducted on *Google scholar* and *Cairn.info* with the previous key words translated in French.

To filter the found articles, a screening process was applied. Documents were first excluded based on their title/abstract and further excluded based the full text where necessary, if they did not meet the following inclusion criteria:

1. Geographical: Europe
2. Sector: residential
3. Topic: acceptability of demand response programs
4. Results: presenting explanatory factors (incentives, barriers, household’s characteristics) of the acceptability/willingness to enrol in demand-side flexibility programs

The whole process can be represented as follows (Fig.4).

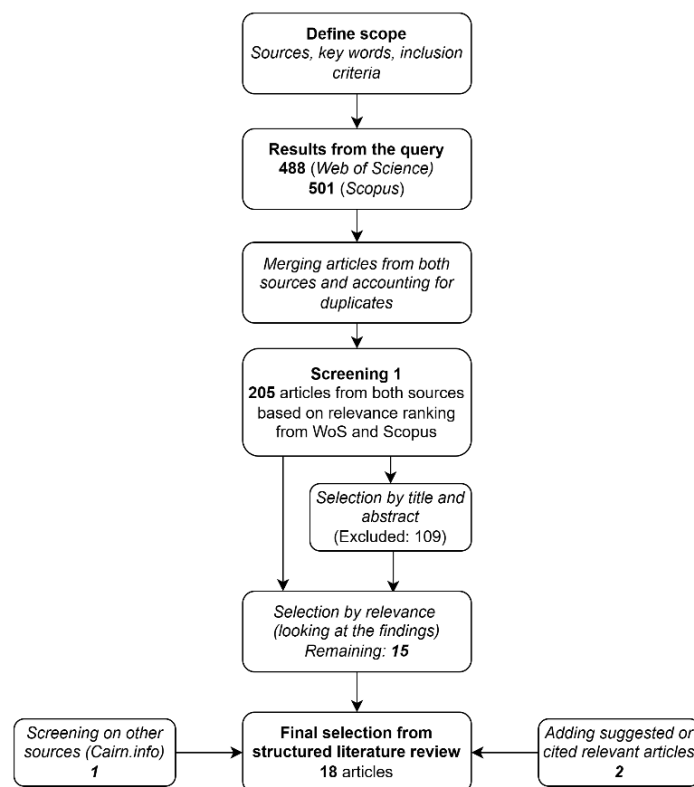


Figure 4. Process of the structured literature review

Following the screening of the literature, the 18 identified documents were reviewed to identify findings on factors affecting residential user’s acceptability of DSF. I was able to identify the obstacles and motivations for flexibility for households. The characteristics of households (variables) influencing their perception of flexibility were also identified.

As the type of DSF varies from one article to another, each document was labelled with the flexibility type and practices considered.

3.2. Survey analysis

3.2.1. Survey design

A survey was conducted prior to my research period by the survey institute IPSOS, commissioned by RTE and carried out between April 28th and May 12th, 2025. I refer to it as *IPSOS_2025* in the rest of this study.

The purpose of the survey was to get a better understanding of household energy consumption, through various themes: mobility, housing, demand-side management and sufficiency, demand-side flexibility.

The survey was answered by 10 221 respondents. The sample was randomly selected among a panel of online respondents from the whole population of French inhabitants of 18 years old and more. The quality of answers was verified with the exclusion of some answers (too quick, draw lines answers...) by the survey institute. To ensure representativity, the quotas method was used by the institute. This means that a coefficient was assigned to each respondent to ensure representativeness and match gender, age, profession and agglomeration category quotas of the French population (*IPSOS_2025*).

The survey collected information on various influencing factors identified in the literature, in particular socio-demographic variables and housing characteristics. The description of the questions can be seen in **Appendix 2**. These questions are referred to as “explanatory variables”, background variables that may influence acceptability.

The survey also assesses the acceptability of demand flexibility. In the *IPSOS_2025*, several questions are considered to assess households’ acceptability of DSF, they are referred to as “dependent variables” (**Table 6**).

Table 6. Questions of the survey used as dependent variables in the analysis, to measure acceptability and current development of DSF (IPSOS_2025)

Label	Question	Possible answers
Q36	Over the last 12 months, have you prioritised certain uses outside peak consumption hours (7am-11am / 6pm-8pm)?	Yes / No for the following appliances: Hot water tank, Washing machine, Dishwashing, Tumble dryer, EV Charging, Electric heating, Heat pump, Kitchen appliances
Q40ST_0	Would you be willing to shift certain uses to midday hours (between noon and 5pm)?	Yes / No
Q40ST_1	Would you be willing to shift certain uses to the late evening (after 8pm)?	Yes / No

Finally, respondents were also asked about the reasons for shifting (or not) their electric uses to off-peak hours (**Table 7**). This part of the survey can be analysed to answer **Q1**. What are the social barriers and drivers that hinder or foster demand-side flexibility among French households?

Table 7. Questions asked about barriers and drivers of DSF (IPSOS_2025)

Label	Question	Possible answers
Q38	What are the reasons that prevent you from consuming (more) outside of peak consumption times (7h-11h / 18h-20h)?	1 st and 2 nd reason among: <ul style="list-style-type: none"> - Consumption when needed - Organisational constraints - Base tariff without on-peak/off-peak difference - No possible programming of the appliance - Little price difference between on-peak/Off-peak - Unawareness of the possibility
Q39	What are your main reasons for making efforts regarding energy use outside of peak consumption times (7h-11h / 18h-20h)?	1 st , 2 nd and 3 rd reason among: <ul style="list-style-type: none"> - Habit or convenience - Lower tariff during off-peak hours - Limiting peak consumptions when greenhouse gases are emitted - Limiting the risk of power outages - Government recommendations - Encouragement from relatives - Self-consumption (e.g. consuming their own electric production)

3.2.2. Analysis

The analysis of the survey is conducted in two phases: an exploratory analysis to contribute to the identification of explanatory variables and an explanatory phase where the influence of previously identified variables will be assessed.

First, a *Chi-square test*, symbolised as χ^2 , was conducted to test the independence of a potential influencing variable and the dependent variable. A *chi-square test* compares the proportion actually observed in the survey with the (randomly drawn) expected proportion to establish if they are significantly different. In the chi-square test of independence, if the χ^2 corresponds to a p-value lower than 0.05, the null hypothesis of independence can be rejected (Onchiri, 2013), and the explanatory variable is considered as having an influence on the dependent variable. This method has been used by many scholars to identify influencing factors of social acceptability of DSF (Ferreira et al., 2022; Li et al., 2017; Schöne et al., 2022; Srivastava et al., 2019).

The data from survey meets the requirements for a chi-square test (Onchiri, 2013):

- Observations based on random selection: some bias may be caused by a random selection among a given panel, but it's considered smaller enough to be able to compute a chi-square test
- Independence of members in the sample
- No group should contain very few items (less than 10). To meet this criterion, some dependent variables were coded by authors (see **Appendix 2** for final coding).
- The overall number of items is large: 10 221 respondents for *IPSOS_2025*
- Analysis conducted with linear constraints

The *Chi-square test* is used here to select, together with the structured literature review, the relevant independent variables that influence acceptability of DSF. A first exploratory analysis of the *Chi-square test* results can be done using the standardised residuals. As explained above, the *Chi-square test* is a comparison between observed frequency and expected frequency, a residual is thus defined as follows (Ahad et al., 2023):

(Eq.1)

$$R_{ij} = (O_{ij} - E_{ij})$$

where i, j denotes the subscript for the rows and columns, O_{ij} the observed frequency and E_{ij} the expected frequency

The sign of the residual indicates a positive or negative contribution from the specific value of the explanatory variable on the dependent variable. To make the residuals easily comparable, they're adjusted and standardised. The adjusted standardised residuals are defined as follows:

(Eq.2)

$$\omega_i = \frac{O_{ij} - E_{ij}}{\sqrt{\{E_{ij}(\beta \times \gamma)\}}}$$

with $\beta = (1 - \frac{r_{ij}}{L})$, $\gamma = (1 - \frac{c_{ij}}{L})$, L the sample size and r_{ij} and c_{ij} the number of rows and columns for the given pair, respectively (Ahad et al., 2023).

For the analysis, the following rules are applied (Ahad et al., 2023):

- If $\omega_i > 2$, the given value of the explanatory variable has a significant positive influence on the dependent variable
- If $\omega_i < -2$, the given value of the explanatory variable has a significant negative influence on the dependent variable
- If $-2 \leq \omega_i \leq 2$, the conclusion on the influence of this specific value

Concretely, if I want to study the influence of gender on acceptability coded as "Yes" / "No" answer. The four standardised residuals are computed for the following pairs: Woman/Yes, Woman/No, Man/Yes, Man/No. If the residual is above 2 for Woman/Yes, it means that being a woman is related to a higher proportion of Yes than expected under the null hypothesis of independence. In easier terms, it would mean that being a woman has a positive influence on the acceptability.

Then, a logistic regression analysis will be conducted with the previously selected explanatory variables. A multivariate regression analysis is relevant when one wants to determine the influence of multiple factors at the same time. The commonly used type of regression is linear regression, represented by the following equation (Eq. 3).

(Eq.3)

$$P(Y = 1) = \hat{Y} = \beta_0 + \sum_i \beta_i X_i$$

With \hat{Y} being the estimated continuous outcome (with $Y = 1$ showing acceptability in that case), X_i being the explanatory variables and β_i the coefficients that indicated how much the outcome (\hat{Y}) increases for a 1-unit increase in the value of the explanatory variable (X_i), β_0 being the intercept considered a constant value (Stoltzfus, 2011).

For the survey, a linear regression would not be appropriate since the dependent variable (willingness to shift more uses) is a categorical variable rather than a continuous one. More specifically, for the logistic regression, the dependent variable is binary coded: “Yes” as 1 and “No” as 0.

According to Stoltzfus (2011), logistic regression is related to the following equation (Eq. 4).

(Eq.4)

$$P(Y = j) = \hat{Y}_j = \frac{e^{\beta_0 + \sum_i \beta_i X_i}}{1 + e^{\beta_0 + \sum_i \beta_i X_i}}$$

In logistic regression, \hat{Y}_j corresponds to the estimated probability of being in one binary outcome (j) versus the other (Stoltzfus, 2011; UCLA : Statistical Consulting group, n.d.).

The logit scale solves this problem by mathematically transforming the original linear regression equation to yield the logit or natural log of the odds of being in one outcome category (\hat{Y}) versus the other category ($1 - \hat{Y}$):

(Eq.5)

$$\ln\left(\frac{\hat{Y}}{1 - \hat{Y}}\right) = \beta_0 + \sum_i \beta_i X_i$$

“Within the context of these equations, logistic regression then identifies, through iterative cycles, the strongest linear combination of independent variables that increases the likelihood of detecting the observed outcome—a process known as maximum likelihood estimation.” (Stoltzfus, 2011).

To interpret the results for a given variable, the odds ratios (ORs) are commonly used. They reveal the strength of the independent variable’s contribution to the outcome and can be expressed as follows:

(Eq. 6)

$$OR(X_i) = \frac{\frac{P(Y = j|X_i = x)}{1 - P(Y = j|X_i = x)}}{\frac{P(Y = j|X_i = x')}{1 - P(Y = j|X_i = x')}} = \frac{Odds(Y|X_i = x)}{Odds(Y|X_i = x')}$$

For a categorical variable, interpretation is done compared to a category of the independent variable set as reference. For a continuous variable, the odds are given for a 1-unit increase in the variable X_i (e.g. $x = x' + 1$ in Eq.4). In concrete terms, if the odds ratio for the variable X_i representing the age is equal to 0.9, then an increase of 1 year for the age means that the odds of being in a situation where $Y = j$ are multiplied by 0.9 (Lavenu, 2015).

To go back to the situation of this study, the dependent variable is the acceptability of a given action, represented by $Y = 0$ for “No” and $Y = 1$ for “Yes” for the questions presented in **Table 6**. The dependent variables are the ones selected from the literature review and the chi-square test, such as age, gender, income, presence of children etc. The description of the questions can be seen in **Appendix 2**.

The analysis is conducted on Python, using the *statsmodels* library.

4. Findings

4.1. Barriers and drivers to demand-side flexibility

The objective here is to answer: **Q1**. What are the **social barriers and drivers** that hinder or foster demand-side flexibility among French households? This section also provides insight into **Q3**. How are **different categories of flexibility actions perceived and accepted**, and how do these perceptions vary according to the identified influencing variables?

First, the structured literature review and the survey analysis led to the identification of eight barriers that hinder DSF acceptability. These barriers are more or less impacting acceptability depending on the flexibility action. This is discussed here using the theoretical framework developed in **Part 2** (categories from **Table 3**).

Then, motivations and incentives are identified and analysed in the same way.

4.1.1. Barriers for users

Structured literature review

As described in the theoretical background, the *theory of practices* gives interesting insights on users' behaviours. This framework emphasizes the role of competences and materials on different practices (Shove et al., 2012). First, a call for the development of smart technologies as *material* requirements of demand-side flexibility arises from engineer sciences (Durillon, 2019), while experts from the ADEME (2024) emphasizes the possibility to engage with demand-side flexibility thanks to the current technologies. The technological barriers (*material* issues) are still mentioned in several pilot programs feedback, with some material not functioning correctly (Nyborg and Røpke, 2013). According to Parrish et al. (2020), the requirement to install new technologies can be a barrier to some households' engagement.

Beyond material aspects, the skills and knowledge required to engage with flexibility mechanisms also constitute an important barrier, referred to as the competence barrier. Bouchet and Chauvin (2015) identify user competences as a key condition for participation, noting that some technologies remain too complex for certain households. This difficulty was observed in the Danish eFlex experiment, where several participants struggled to operate the control interface effectively (Nyborg and Røpke, 2013). Similarly, the complexity of flexibility-oriented electricity contracts, particularly those involving variable pricing or detailed contractual conditions, can reduce households' willingness to enrol. Empirical evidence suggests that users tend to favour simpler and more predictable pricing structures (Ruokamo et al., 2019). More broadly, energy-related knowledge shapes how households respond to flexibility incentives: understanding the consumption levels of different appliances influences which practices users are choosing to adapt (Öhrlund et al., 2019), while lower levels of energy literacy are associated with lower acceptance of DLC arrangements (Andolfi et al., 2024).

To continue with the theory of practices, being flexible can cause the disruption of households' habits or routines, which can be difficult to accept.

First, as discussed in the theoretical framework, the temporality of flexibility actions can interfere with household's habits and practices. This disturbance of households' habits is inconvenient to households. Convenience is defined by Shove (2003) as "associated with the capacity to shift, juggle and reorder episodes and events" (Friis and Haunstrup Christensen, 2016; Öhrlund et al., 2019). DSF actions tend ironically to reduce the flexibility of daily life. The level of inconvenience caused by DSF highly depends

on the concerned use. For instance, dishwashing and laundry were considered easy to shift by most of the participants (Öhrlund et al., 2019). The reaction to different incentives is also guided by the perceived inconvenience for users: predictability is highly valued when it comes to price signals. Even when tariffs are not regular, households try to identify a recurring pattern to use as a rule for the new timing of their domestic practices (Öhrlund et al., 2019).

As well as convenience, the question of *comfort*, understood as “feeling comfortable in one’s home” (Hansen et al., 2019, p.2), matters for households. In fact, impacts on comfort decrease the acceptance of DLC (Parrish et al., 2020). The concept of comfort can encompass various parameters: temperature, daylight, noise, fresh air and functionality (Hansen et al., 2019). However, since the supplementary effort of DSF actions and the disruption of habits are tackled by the inconvenience, the notion of comfort will further be used as the *thermal comfort*. Empirical studies show that guarantees regarding minimum indoor temperatures are a decisive factor in the acceptance of flexibility contracts (Bender et al., 2024), which clearly shows that the idea of losing thermal comfort is an obstacle to DSF. Sensitivity to comfort constraints also varies across household structures: families with young children, for example, are more likely to prioritise stable thermal conditions (Nyborg and Røpke, 2013). Nevertheless, evaluations of pilot projects suggest that, in practice, participants often experience only limited reductions in comfort (Danish eFlex: Nyborg & Røpke, 2013).

Moreover, *privacy concerns* are often raised by households regarding demand-side flexibility (Bender et al., 2024; Bouchet and Chauvin, 2015; D’Ettorre et al., 2022). These concerns are related to two different situations. First, automation, particularly in the form of Direct Load Control, may be perceived as a *loss of control*, as control over certain appliances is transferred to an external actor. In this regard, some users prefer automated systems over DLC that they can override themselves, as these are seen as preserving a greater sense of control (Parrish et al., 2020; Tomat et al., 2023). This loss of control is seen as a dispossession for households and DLC should come with opt out options (Barthe et al., 2015). Second, privacy concerns also relate to the collection and *sharing of consumption data* with utilities or aggregators (Wen et al., 2025), an issue that has been widely debated in France, particularly in relation to the deployment of Linky smart meters. More generally, households tend to be highly sensitive to any form of external intervention within the domestic sphere (Bender et al., 2024).

Finally, an economic barrier is to be overcome. This economic obstacle includes the supplementary costs that may be required to replace the appliance, buy an additional device or for maintenance costs (D’Ettorre et al., 2022). Also, tariffs may not be adapted for flexibility, and costs benefits would thus appear as too small for the users (D’Ettorre et al., 2022).

These findings are summarised in **Table 8**.

Table 8. Findings from the structured literature review on the barriers to DSF

Barrier	Type of flexibility and source
Material: need for new technologies, or malfunctioning	Automated or centralized manual flexibility (Nyborg and Røpke, 2013; Parrish et al., 2020)
Competences: too complex technologies or price schemes, energy literacy	Automated or centralised manual flexibility (Andolfi et al., 2024; Bouchet and Chauvin, 2015; Nyborg and Røpke, 2013) Manual shifting (Tomat et al., 2023) Dynamic flexibility (Ruokamo et al., 2019)
Inconvenience: disturbance of households' habits and of other practices	Manual shifting (Friis and Haunstrup Christensen, 2016; Öhrlund et al., 2019)
Thermal comfort	DLC (Bender et al., 2024; Parrish et al., 2020)
Privacy concerns: loss of control	Automated DSF and DLC (Barthe et al., 2015; Parrish et al., 2020; Tomat et al., 2023)
Privacy concerns: data sharing	DLC (Bender et al., 2024; Wen et al., 2025) Automated flexibility (Tomat et al., 2023)
Economic barrier: supplementary costs	DLC (D'Ettoire et al., 2022)
Economic barrier: inadequate tariffs	DLC (D'Ettoire et al., 2022)

Survey

In the survey *IPSOS_2025*, respondents were asked about their reasons for not shifting more their energy consumptions to off-peak hours, as described in the methodology part (**Table 7**). The results are presented on **Figure 5**.

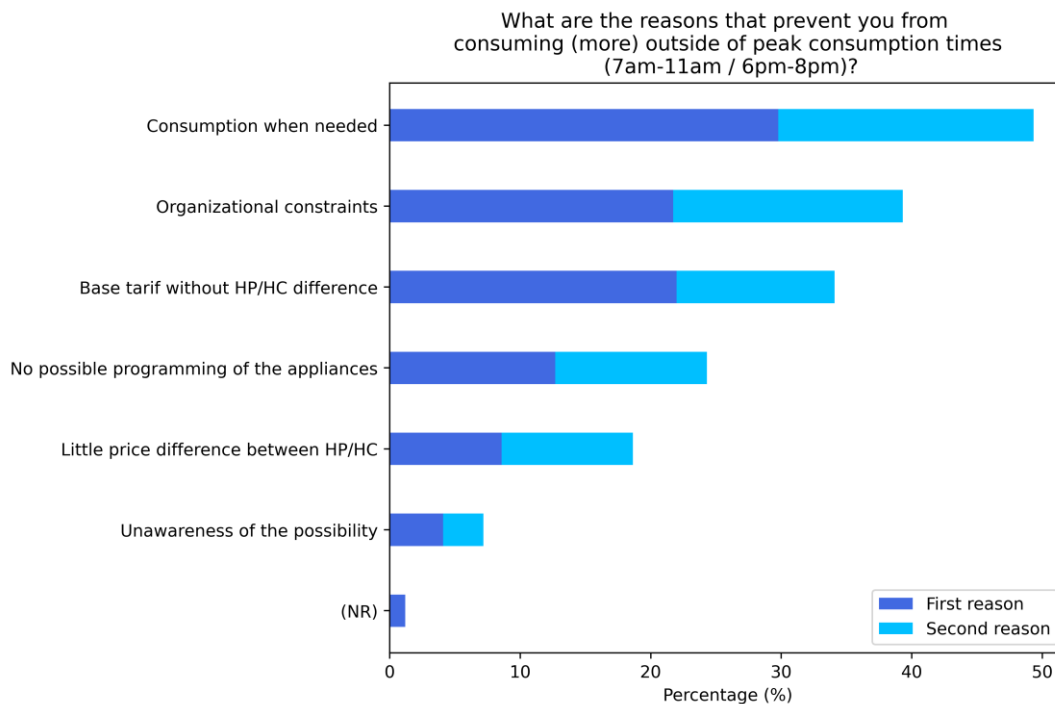


Figure 5. Barriers to shifting more uses to off-peak hours (IPSOS_2025)

The possible answers in the survey were more precise than the general barriers identified in the previous part. They can be related to the previously identified barriers as follows (Fig. 6):

- Consuming when necessary and organisational constraints → Inconvenience
- Fixed tariff without distinction between on peak and off-peak hours → Economic barrier
- No possibility to program appliances → Material barrier
- Small price difference between on peak and off-peak hours → Economic barrier
- Unknown possibility → Competences

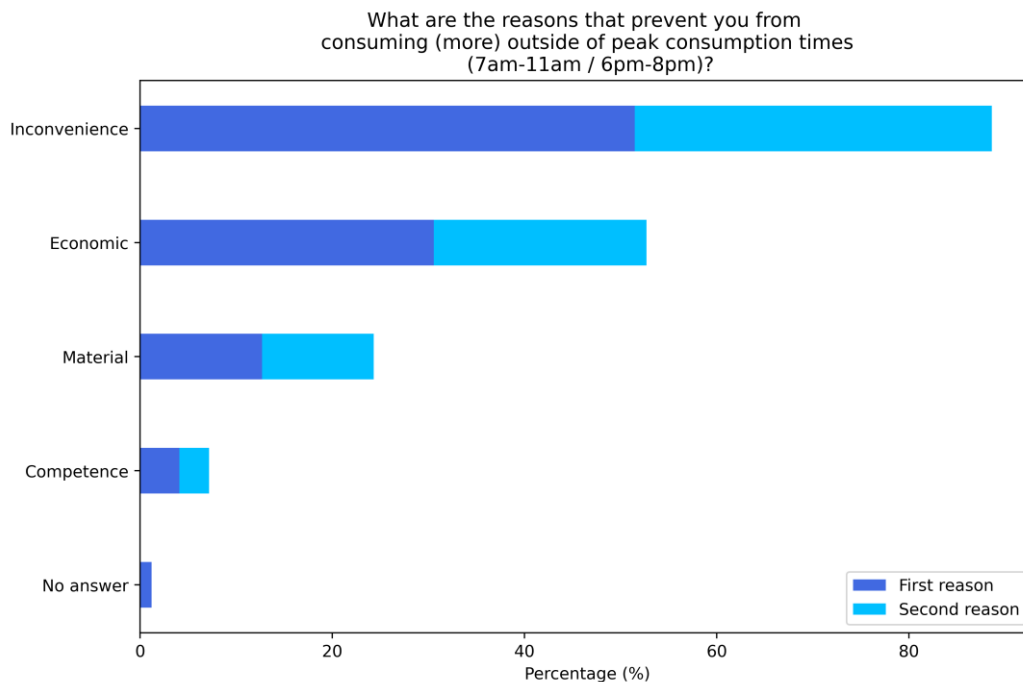


Figure 6. Main barriers to households' contribution to manual flexibility (IPSOS_2025)

According to these results (Fig. 6), inconvenience is the main barrier to manual shifting. The economic barrier, mostly a lack of economic incentives here, is the second one, followed by material barrier for centralized manual control. The question of competences, more precisely the knowledge of on peak/off-peak hours and the possibility to shift activities, is less important (less than 10% of mention).

Barriers depending on the flexibility category for user

Drawing on both the survey results and the literature review, this section identifies the main barriers limiting household engagement in demand-side flexibility. In line with the analytical framework (Table 3), these barriers cannot be assessed independently of the specific characteristics of each category of flexibility action. Accordingly, beyond identifying barriers common to all forms of flexibility, the following discussion highlights how their relative importance varies across categories and how different barriers interact. These differentiated effects are synthesized in Table 9, which provides an overview of the relative weight of each barrier for the various flexibility actions.

The empirical findings from the survey primarily inform the analysis of manual flexibility actions (categories 1 to 4 in Table 3), whereas the literature allows the discussion to be extended to all categories, including automated and third party-controlled solutions. First, an opposition can be observed between *inconvenience* on one side and *privacy concerns* and *loss of control* on the other side.

On one hand, automated solutions, especially DLC, come with privacy concerns and perception of loss of control for households (Bouchet and Chauvin, 2015; D’Ettorre et al., 2022; Parrish et al., 2020). The perception to lose control is greater with DLC than automation (Parrish et al., 2020) and also depends on the appliances it applies to. According to D’Ettorre et al. (2022), the sense of losing control is also higher when programming home appliances like washing machine to be completed by a given time than when programming EV charging. Also, households would rather change the consumption at their discretion even if it’s more difficult (Tomat et al., 2023).

On the other hand, automation can be considered more convenient for households, as it does not require additional actions from the user. In fact, the study from (Tomat et al., 2023) shows high agreement with the following sentence “Giving control to the utility would allow me to save time”. The same results are observed with “smart technologies” in general.

Inconvenience is also the main obstacle to household’s willingness to shift manually their consumption (IPSOS_2025). Even among manual categories, a distinction can be made between the ones with enabling technologies (Centralized manual) and the ones without (manual). As described by Parrish et al. (2020), enabling technologies do facilitate flexibility, thus reducing inconvenience for households. In fact, the ability to remote control their appliance can reduce the disruption of other practices at home. Also, the regularity of the flexibility has an impact on the inconvenience for households. Regular flexibility means disruption of pre-existing routines. This leads to a high obstacle at the beginning, as some households want to keep consuming when needed (IPSOS_2025). However, when implemented in the daily lives, these new ways of consuming can become habits. For instance, off-peak hours at night have been implemented in France for a long time and using the dishwasher at night can become part of a new routine. In the survey, the first reason for people to shift their consumption is that it’s become a habit (IPSOS_2025). Also, Friis and Haunstrup Christensen (2016) explain that “the already harried mornings are flexible to change and reschedule due to an already high level of detailed coordination and planning” for families with children. Dynamic flexibility is inconvenient both for manual shifting because it does not rely on new habits and lead to high constraints on few specific days, but also for Direct Load Control as flexibility calls may come at inconvenient times for households. The opt-out options to tackle this inconvenience is even the second most important factor in the choice of contract, according to Bender et al. (2024). Moreover, as described by Barthe et al. (2015), flexibility measures can pose a problem during social events, such as when the household has guests. HEMS are designed to follow household’s preferences, so that the inconvenience should not be an issue.

Moreover, competences can be an important barrier when the user needs to engage with a specific technology. HEMS can be difficult to understand for users (D’Ettorre et al., 2022). The difficulty to access information regarding their energy consumption can reduce user’s engagement in demand response (Parrish et al., 2020). For Bouchet and Chauvin (2015), the user experience needs to be considered when designing smart-grid technologies in order to make it easy to use. Specifically, they insist on the accessibility, understood as the adaptation of the technology to all users, to reduce the need for specific competences. Manual changes require more competences from the users if they are to be made correctly for the grid. In particular, access and possibility to use enabling technologies like appliance timers increases engagement with demand-side flexibility (Parrish et al., 2020).

The economic barriers represented by additional costs of installation and maintenance are especially relevant for automated solutions like DLC (D’Ettorre et al., 2022). The issue of inadequate tariffs is overall the same for all categories, as it’s not related to the type of actions. However, the benefits from being flexible need to be higher when there are important losses in comfort and convenience (Bender et al., 2024).

Based on these differentiated effects, **Table 9** provides a synthetic overview of the relative importance of each barrier across the categories of flexibility actions. **Table 9** can be read in two ways. It shows the order of importance of barriers for each flexibility category (read horizontally) and the order of categories for a given barrier according to the impact that barrier has on those categories (read vertically). Thus, a high barrier for a category means that overcoming that obstacle will have a real influence on the acceptability of that flexibility category. This assessment has been made by the author and draws both on explicit evidence from the literature and survey results and on analytical extensions derived from the defining attributes of each category. 'No' indicates that the barrier is not mentioned in the literature or survey for the flexibility category under consideration. "Small", "medium" and "high" give the level of importance of a barrier on a given category of flexibility. To create this table, "High" and "Small" were assigned based on the literature, according to the importance given to this barrier by publications, as discussed above. "Medium" was then used to refine the order of importance of the barriers. The order of barriers found in the survey results was also used to refine the ranking.

Table 9. Level of barriers depending on the category of flexible sources for users (made by author). "No" means that the barrier does not apply to the category. The level of importance of the barrier for a given category is then visible through the colour distinction and the legend "Small", "Medium", "High"

Categories from Theoretical Framework	Material	Competences	Privacy concerns		Inconvenience	Loss of comfort	Economic barriers	
			Data sharing	Loss of control			Inadequate tariffs	Costs
1.Manual Regular	No	Small	No	No	High	Small	High	Small
2.Manual Dynamic few days	No	Small	No	No	Medium	Medium	High	Small
3.Centralized manual Regular	Small	Medium	No	No	Small	Small	Medium	Medium
4.Centralized manual Dynamic few days	Small	Medium	No	No	Medium	Medium	High	Medium
5Automatic Regular	Medium	No	No	Small	No	/	Medium	Medium
6Automatic Dynamic	Medium	No	No	Small	No	/	Medium	Medium
7.DLC Dynamic few days	High	Small	High	High	Small	High	Medium	Medium
8.DLC Dynamic everyday	High	Small	High	High	Small	High	Medium	Medium
9.HEMS	High	Medium	High	Medium	No	No	Medium	Medium

4.1.2. Incentives and drivers to DSF

In this section, the incentives and drivers to DSF are identified to understand why people decide or can contribute to DSF. As for the barriers, the analysis is conducted through the structured literature review and the survey analysis.

Structured literature review

In their work, Caron and Durand-Daubin (2016) identified the main reasons for participating in the load reduction project. These motivations can be grouped into four broad dimensions. The first relates to

economic considerations, including the desire to reduce electricity bills, monitor consumption more closely, and benefit from financial incentives or favourable contractual arrangements. A second dimension concerns environmental motivations, such as reducing energy use, avoiding waste, improving efficiency, supporting self-consumption, and favouring environmentally friendly production methods. Participation may also be driven by an interest in innovation, encompassing curiosity for new technologies or social practices, the willingness to experiment, share experiences within one's social circle, and confidence in technological progress. Finally, civic responsibility plays a role, reflecting attachment to the local community, concern about consumption peaks, and a sense of individual responsibility toward the collective functioning of the electric system.

Firstly, the cost savings resulting from flexibility measures are the main motivation for households (Parrish et al., 2020). This is the case for manual flexibility (Tomat et al., 2023), based on DLC (D'Etterre et al., 2022; Schöne et al., 2022) or supported by HEMS. (Pfeiffer et al., 2021). Contract choice experiments further indicate that higher expected annual savings significantly increase the likelihood of households opting for flexibility-oriented tariffs (Ruokamo et al., 2019).

Environmental benefits are also a strong motivation (Parrish et al., 2020). Pfeiffer et al. (2021) identified the following motivations for using HEMS: the fact that it is a more sustainable solution, its contribution to environmental protection, and the increased use of renewable energy. For flexibility contract, an increase in the environmental benefits, through carbon emission reductions for instance, results in a higher probability to choose this contract (Ruokamo et al., 2019). According to D'Etterre et al. (2022), the environmental benefits are a key incentive for DLC, with 23% of French respondents in their study mentioning a reduction of their environmental impact as a driver for DLC for EV charging. Similar results were found by Wen et al. (2025) for DLC, or manual centralised control of Heat Pump.

Civic responsibility is also an incentive to DSF, the contribution to a safer and more stable energy grid being the mentioned by 15% of the respondents for DLC in France (D'Etterre et al., 2022). Contributing to the electricity system reliability has been identified as a motivation for DSF (Parrish et al., 2020). Civic responsibility, through a high sense of community was found to be a great driver to flexibility in the Island of Mayotte (Schöne et al., 2022).

By contrast, innovation-related motivations appear more uneven across flexibility types. For Direct Load Control applied to appliances such as electric vehicles or washing machines, perceived technological drawbacks often outweigh perceived benefits (D'Etterre et al., 2022). In the case of Home Energy Management Systems, however, interest in new technologies and trust in scientific and technical progress significantly increase the likelihood of adoption, suggesting that innovation can act as a driver for specific user profiles (Pfeiffer et al., 2021).

For manual shifting, consuming outside of on-peak hours can also become part of a household's routine. That's what Li et al. (2017) show with people working from home who already consume during off-peak times. Other studies indicate that even households with tightly structured schedules may adapt their practices when new constraints are introduced, particularly when flexibility can be integrated into existing routines (Friis and Haunstrup Christensen, 2016).

Encouragement from relatives can also increase a household's willingness to enrol in a DSF program. Encouragement from relatives or peers has been shown to increase confidence in flexibility schemes, especially when households can rely on prior experiences within their social environment (Tomat et al., 2023). According to D'Etterre et al. (2022), encouragement from relatives is a minor incentive for DLC compared to cost savings, environmental benefits and ease of use. Parrish et al. (2020) refer to discussion with neighbours and encouragement from children as an identified incentive in some studies.

Table 10. Summary of the structured literature review for motivation to DSF

Incentive	Type of flexibility and source
Cost savings	Manual shifting (Caron and Durand-Daubin, 2016; Tomat et al., 2023), DLC (D’Ettorre et al., 2022; Schöne et al., 2022), HEMS (Pfeiffer et al., 2021), dynamic flexibility in general (Ruokamo et al., 2019)
Environmental benefits	Manual shifting (Caron and Durand-Daubin, 2016), DLC (D’Ettorre et al., 2022; Wen et al., 2025), HEMS (Pfeiffer et al., 2021), dynamic flexibility (Ruokamo et al., 2019), DSF in general (Parrish et al., 2020)
Civic responsibility	Manual shifting (Caron and Durand-Daubin, 2016), DLC (D’Ettorre et al., 2022; Schöne et al., 2022), DSF in general (Parrish et al., 2020)
Innovation	Manual shifting with smart technology (Caron and Durand-Daubin, 2016), small for DLC (D’Ettorre et al., 2022), HEMS (Pfeiffer et al., 2021)
Encouragement from relatives	Smart technologies (Tomat et al., 2023), small for DLC (D’Ettorre et al., 2022), DSF (Parrish et al., 2020)
New habits / routines	Manual shifting (Li et al., 2020)

Survey

In the survey *IPSOS_2025*, respondents were asked about their reasons for shifting their energy use outside of peak consumption hours. The results are presented on **Figure 7**.

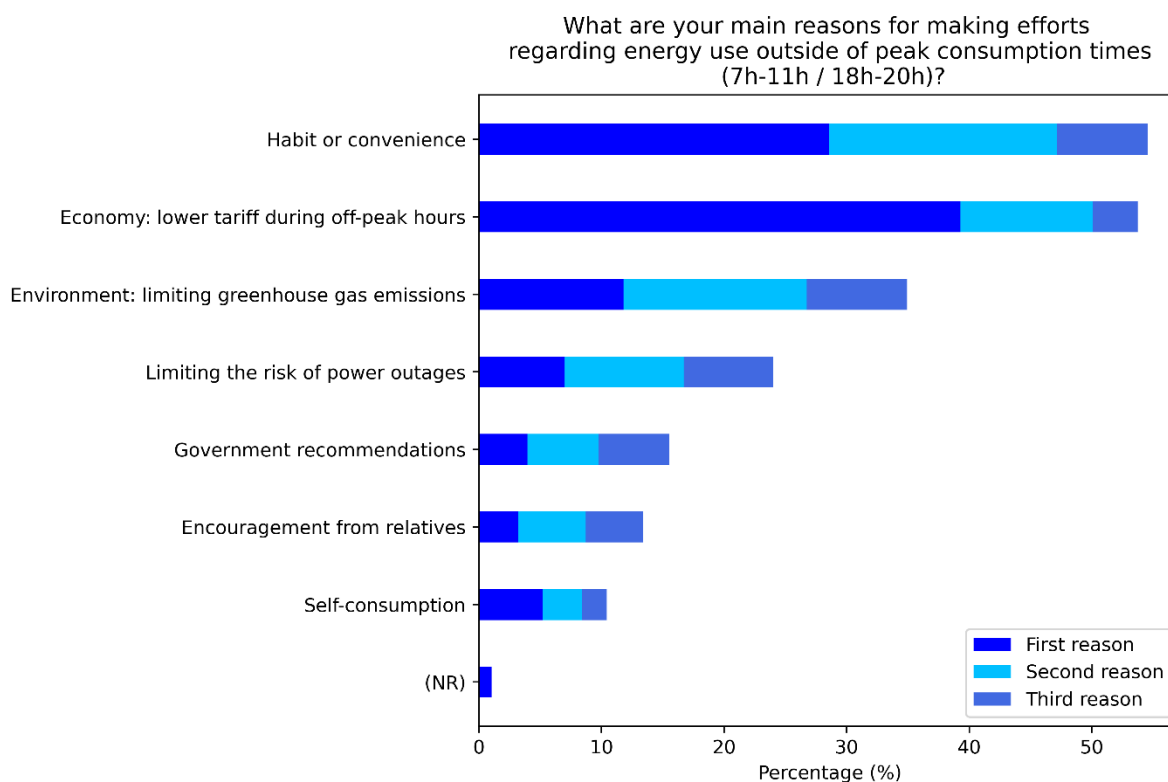


Figure 7. Survey results of incentives for a consumption outside of peak hours (IPSOS_2025)

The possible answers in the survey were more precise than the general incentives identified in the literature. They can be related to the previously identified incentives as follows (**Fig.8**):

- Habit and convenience
- Lower tariffs → Cost savings
- Limiting greenhouse gas emissions → Environmental benefits
- Limiting the risk of power outages → Civic responsibility
- Government recommendations → Civic responsibility
- Encouragement from relatives
- Self-consumption → Environmental benefits

As shown by **Figure 8**, for manual shifting, new habits and cost savings are the main drivers, cost savings being the first reason mentioned by respondents. Environmental benefits are also an important driver. Civic responsibility and encouragement from relatives are also mentioned.

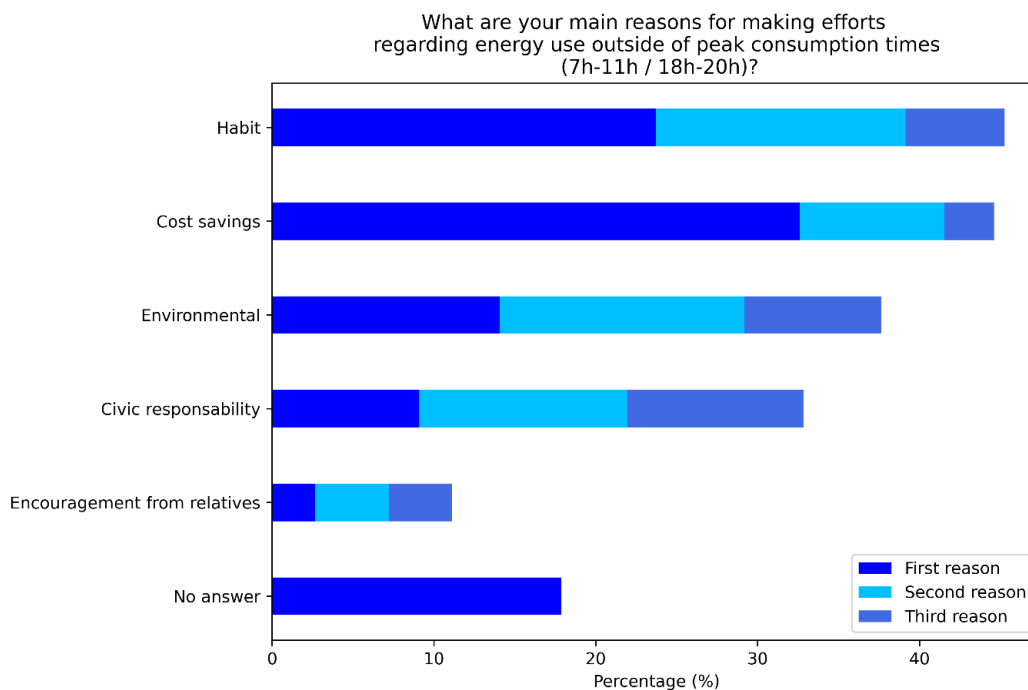


Figure 8. Survey results for incentives (recoded) (IPSOS_2025)

Incentives depending on the flexibility category

The savings achieved are the main motivation for all modes of flexibility (D’Ettorre et al., 2022; Parrish et al., 2020; Tomat et al., 2023, IPSOS_2025). However, it should be noted that greater discomfort is accepted in exchange for greater economic compensation (Bender et al., 2024). On first approximation, to allow a comparison between different incentives, cost savings are considered as a high motivator for all categories. A more detailed distinction from one category to another could be presented in a future study.

For manual flexibility, the evolution of habits was the second driver (IPSOS_2025), while environmental benefits are the second for other categories of flexibility (D’Ettorre et al., 2022; Parrish et al., 2020).

Interest in technology and in innovation is relatively high among the potential users highlighted by Pfeiffer et al. (2021). Innovation in terms of practices can be a motivator for other categories of flexibility (Caron and Durand-Daubin, 2016).

Encouragement from relatives is a small motivator compared to other for manual flexibility (IPSOS_2025). However, for direct load control and HEMS, the concerns that come with smart technology are higher. It translates into a higher need for encouragement, people feeling more comfortable to use these technologies if they have been tried by relatives before (Tomat et al., 2023).

Based on the distinctions discussed above, **Table 11** provides a synthetic overview of the incentives associated with demand-side flexibility, assigning a relative weight to each incentive according to the different categories of flexibility actions. Rather than treating motivations as uniform across households, this summary highlights how their importance varies with the constraints associated with each category (see framework in **Table 3**). The weighting presented in **Table 11** combines direct evidence from the literature and survey results with an analytical assessment grounded in the defining characteristics of each flexibility action, thereby offering a comparative reading of the drivers shaping household engagement in demand-side flexibility. As for **Table 9**, “High” and “Small” were firstly assigned based on the literature, and “Medium” was then introduced to obtain a ranking. The order of motivations observed in the survey results was also used to refine the ranking. “No” still indicates that the incentive does not apply for the given category of flexibility.

Table 11. Incentives and drivers to DSF depending on the category of DSF actions (made by author)

Categories from Theoretical Framework	Cost savings	Environmental benefits	Innovation	Responsibility	Evolution of habits	Encouragement from relatives
1.Manual Regular	High	Medium	No	Small	High	Small
2.Manual Dynamic few days	High	Medium	No	Small	High	Small
3.Centralized manual Regular	High	Medium	Small	Small	High	Small
4.Centralized manual Dynamic few days	High	Medium	Small	Small	High	Small
5Automatic Regular	High	Medium	Small	Small	Small	Small
6Automatic Dynamic	High	Medium	Small	Small	Small	Small
7.DLC Dynamic few days	High	Medium	Small	Small	Small	High
8.DLC Dynamic everyday	High	Medium	Small	Small	Small	High
9.HEMS	High	Medium	High	Small	Small	High

In this section, eight barriers to flexibility and six motivators have been identified, thus answering **Q1**. Their importance according to flexibility categories has also been assessed (**Table 9** and **Table 11**), thus giving a first answer to **Q3**.

In the next section, I will focus on the characteristics of households that influence their acceptability of DSF solutions. I will return to the perception of barriers and incentives according to household characteristics in section 4.3.

4.2. Influencing variables to social acceptability of DSF

Clearly, the obstacles and drivers to flexibility identified previously vary from one household to another, depending on their situation. The objective here is to understand which variables influence a household's response to, and acceptance of DSF, thus responding to **Q2**. Which *variables* influence the acceptability of various types of demand-side flexibility based on household characteristics and organisation?

From the structured literature review, I was able to identify variables that influence social acceptability of DSF in Europe (part 4.2.1). The influence of these variables is then tested in the French situation, for manual flexibility, using the survey results (part 4.2.2).

4.2.1. *Influencing variables to social acceptability in Europe*

The variables that influence the social acceptability of flexibility were identified thanks to the structured literature review. Three themes emerged from the literature: socio-demographic factors, household composition and organisation, and values.

Socio-demographic factors

Socio-demographic factors influence the acceptability of the DSF, according to numerous studies. (Andolfi et al., 2024; Bender et al., 2024; Parrish et al., 2020; Ruokamo et al., 2019). However, some researchers have shown more nuanced results. For example, Sridhar et al. (2023b) found that socio-demographic factors had no effect on the general acceptability of DLC, while Li et al. (2020) found that heterogeneity of results depended on the use considered.

Let us take a closer look at the socio-demographic factors to consider.

Firstly, age is an important influencing factor. Studies tend to show that older people are reluctant to embrace flexibility, whether in the form of DLC (Parrish et al., 2020; Schöne et al., 2022; Sridhar et al., 2023b) or of manual shifting. For manual shifting of activities, Li et al. (2020) observed a consistent influence of age on usage. According to their results, respondents over the age of 55 are more likely to be reluctant to shift any of the six uses considered. One interpretation of these results for heating is to consider the greater vulnerability of older people to cold temperatures and to understand health considerations behind this reluctance. However, the results of Tomat et al. (2023) show that 26-40 year olds are less inclined to shift their activities than other age groups. For DLC, younger people are also more motivated to participate in flexibility for heating or EV charging (Sridhar et al., 2023a). In contract choices, Broberg and Persson (2016) observed a correlation between increasing age and the choice of the status quo contract rather than flexibility offers. Ruokamo et al. (2019) were the only ones to find people over 60 as more likely to select flexibility contracts.

Older people are more sensitive to information sharing, perhaps because they are less used to sharing information in general (Broberg and Persson, 2016). This points out the duality hidden behind the variable "Age". In fact, age can show differences of generations (knowledge on how to use technology, data sharing) but also differences due to the conditions of that age (cold sensitivity of elderly, more time spent at home for young and elderly...).

Secondly, households with the lowest incomes seem more inclined to shift their usage, particularly for heating (Li et al., 2020). This seems consistent with the findings in the previous section indicating

savings as the main motivation. Similarly, Tomat et al. (2023) observed greater reluctance among wealthy households to change their habits in favour of manual flexibility. Regarding the choice of flexibility contract, Broberg and Persson (2016) demonstrated a positive correlation between the choice of the status quo contract and increased income. With regard to DLC, Schöne et al. (2022) also demonstrated that income has a strong influence on interest in DLC. However, according to Ruokamo et al. (2019), income has no influence.

The education of the user also influences their willingness to contribute to DSF. Highly educated households tend to be more willing to participate in DSF than low-educated ones (Broberg and Persson, 2016; Ruokamo et al., 2019). This finding was confirmed for DLC of electric vehicle charging (Sridhar et al., 2023b) and DLC of heating (Andolfi et al., 2024). For manual shifting, Li et al. (2017) depict heterogeneity depending on the activity to shift. The interpretation would be that high educated households get a better understanding of the benefits of DSF. For Andolfi et al. (2024), the energy literacy of households impact their acceptability of DSF, an indirect factor that could explain the observed difference between high and low-educated households.

On the other hand, the influence of gender is more controversial. While some find that gender influences participation in demand response programmes, with women being more inclined to participate (Tomat et al., 2023), others showed that this influence is not significant in aggregate terms (Li et al., 2017; Ruokamo et al., 2019). In terms of usage, differences are visible on a case-by-case basis: men respond that they are more inclined to postpone cooking but less inclined to postpone laundry (Li et al., 2017). Similarly, the use of smart technologies is more widespread among men, who say they are more inclined to use them (Tomat et al., 2023).

Finally, variations in responses were observed depending on geographical area by Li et al. (2017) and Schöne et al. (2022). However, these influences vary from country to country and are often linked to the local context. It will be necessary to examine whether such an influence is observed in the French case.

Household structure and organisation

Household characteristics influence their acceptance of flexibility measures, particularly those related to household organisation such as presence of children, type of housing, occupancy of the dwelling.

Several studies have shown that spending more time at home facilitates flexibility (Parrish et al., 2020). Regarding manual shifting, Li et al. (2020) observed that people with flexible working hours or who spent more time at home already had staggered domestic activities and did not represent potential for an increase in flexibility potential. For categories of flexibility including remote control, this variable could become irrelevant. That's what Tomat et al. (2023) wanted to show to their respondents : "through smart technologies, one can change their consumption even if they are not at home or sleeping".

The current organisation of households also plays a key role in their desire to be more flexible. As discussed in relation to the obstacle of inconvenience, there are strong links between different everyday practices. Furthermore, the current timing of electrical appliance use influences the desire to shift it or not (Li et al., 2020).

Households without dependents (especially without children) appear more inclined to participate in demand response programmes (Parrish et al., 2020; Schöne et al., 2022). In fact family time is important for families with children, and certain changes in habits would be too restrictive (Friis and Haunstrup Christensen, 2016). Furthermore, the desired level of thermal comfort is higher when young children are present.(Caron and Durand-Daubin, 2016). Indeed, shifting usage patterns can be more

difficult for families with children who already have tight schedules. While this may explain the findings of Tomat et al. (2023) who observed a reluctance to shift usage patterns such as laundry, Friis and Haunstrup Christensen (2016) offer a different analysis. According to some of the families interviewed, their busy schedules can easily be adjusted to accommodate new habits. In the same idea, the control trial conducted by Yilmaz et al. (2019) shows that households with children in Switzerland are more likely to be successful in shifting their electricity use. This is because they are more at home at noon to have lunch with their children, thus able to combine with other practices during those off-peak hours.

While the presence of children seems to reduce the acceptability of flexibility, household size has been observed to positively influence responses to demand response programmes. This positive response from larger households may be linked to their higher consumption, which leads to greater economic benefits (Li et al., 2017). For Friis and Haunstrup Christensen (2016), household size is not directly related to the degree of activity shift.

Moreover, the dwelling type can impact the acceptability of the DSF. According to Li et al. (2017), this effect is reflected in variations in preferences for postponing certain tasks. For example, people living in flats are more reluctant than those living in houses to postpone doing laundry. This may be due to the fact that noise is more of a nuisance in flats. A difference according to type of housing is also observed by Schöne et al. (2022) for contract modalities. For example, people living in flats want to receive information further in advance before a flexibility episode.

Another characteristic of the dwelling to consider is its thermal insulation, which affects thermal comfort and inertia. Flexibility is facilitated by better insulation and access to other heating modes (Parrish et al., 2020). According to Broberg and Persson (2016), indoor room temperatures also plays a role : higher indoor temperatures correspond to greater reluctance to give control of the heating, particularly between 5 and 8 pm.

In addition, home owners are showing greater willingness to be flexible (Parrish et al., 2020).

Values

Finally, individuals' values and attitudes influence their acceptance of flexibility.

Firstly, individuals who are concerned about the environment are more inclined to contribute to electricity flexibility (Bender et al., 2024). This is entirely consistent with the environmental benefits of the DSF as the second main motivation. Andolfi et al. (2024) demonstrated the importance of environmental values, whether for heating or charging electric vehicles. The importance of environmental values is also evident in the findings of Broberg and Persson (2016) who highlight that members of environmental organisations are less likely to choose the status quo.

Also, the attitudes toward energy savings are related to household's willingness to contribute to DSF. For Li et al. (2017), the more worried/interested they are in energy saving, the more they are willing to shift their dishwashing or laundry use.

Trust in technology is also mentioned by several scholars (D'Ettoire et al., 2022; Pfeiffer et al., 2021). This relates to innovation being a good incentive and loss of control as a key obstacle. People who trust technology thus seem more likely to accept DLC and other technology-driven flexibility. Bender et al. (2024) mention trust in general as a factor of influence. This also relates to the privacy concerns represented by DLC.

Table 12. Influencing variables to social acceptability of DSF identified in the structured literature review

Theme of variable	Variable	Type of flexibility and sources
Socio-demographic factors	Age	DLC (Parrish et al., 2020; Schöne et al., 2022; Sridhar et al., 2023a) Manual shifting (Li et al., 2020; Tomat et al., 2023) Dynamic flexibility (Broberg and Persson, 2016; Ruokamo et al., 2019)
	Gender	Smart technologies (Tomat et al., 2023) Manual shifting – variation depending on the practice (Li et al., 2020)
	Income	Manual shifting (Li et al., 2020; Tomat et al., 2023) DLC (Schöne et al., 2022) Dynamic flexibility (Broberg and Persson, 2016)
	Education	DLC (Andolfi et al., 2024; Sridhar et al., 2023a)
	Geographic area	Manual shifting (Li et al., 2020)
Housing and household characteristics	Number of inhabitants	Manual shifting (Li et al., 2020) No influence (Friis and Haunstrup Christensen, 2016)
	Presence of children	General DSF (Parrish et al., 2020; Yilmaz et al., 2019) Manual flexibility (Friis and Haunstrup Christensen, 2016; Tomat et al., 2023), Heating (Caron and Durand-Daubin, 2016) DLC (Schöne et al., 2022)
	Homeownership	General DSF (Parrish et al., 2020)
	House occupancy (working from home)	General DSF (Parrish et al., 2020) Manual flexibility (Li et al., 2020) Less influence for smart technologies (Tomat et al., 2023)
	Dwelling type	Laundry (Li et al., 2020) DSF in general (Schöne et al., 2022)
	Thermal comfort and insulation	Heating (Broberg and Persson, 2016; Parrish et al., 2020)
Values	Environmental awareness	DLC (Andolfi et al., 2024) General DSF (Broberg and Persson, 2016)
	Attitudes toward energy saving	Manual flexibility (Li et al., 2020)
	Trust in technology	DLC (D’Ettorre et al., 2022) HEMS (Pfeiffer et al., 2021)
	Trust	General DSF (Bender et al., 2024)

In this section, the main influencing variables of acceptability were identified for different DSF categories (**Table 12**). These findings are then tested in the French context for manual flexibility.

4.2.2. Empirical analysis: Influence of variables on the social acceptability of manual flexibility (χ^2 and regression results)

This section builds upon the observations made in the preceding structured literature review (**Table 12**), which identified a range of variables likely to play a role in shaping the social acceptability of demand-side flexibility (DSF). The present analysis seeks to test these insights within the specific context of the French survey sample, for manual flexibility. It applies both chi-square tests of independence and multinomial logistic regression to capture both bivariate and multivariate relationships between explanatory variables and willingness to engage in manual flexibility.

Most of the explanatory variables identified in the previous section were already measured by the IPSOS survey. Details of the variables included in the survey, as well as information on the recoding

that was carried out, are available in **Appendix 2**. A statistical summary of the survey sample is presented **Appendix 3**.

The dependent variables considered for the analysis are the following (see **Table 6**):

- Q40ST_0 - Would you be willing to shift certain uses to midday hours (between noon and 5pm)?
- Q40ST_1 - Would you be willing to shift certain uses to the late evening (after 8pm)?

These questions allow to study the acceptability of regular manual flexibility by households (categories 1 and 3 in the analytical framework – see **Table 3**). Overall, 70% of respondents are willing to shift certain activities to late evening and 80% are willing to shift to midday hours (**Fig. 9**).

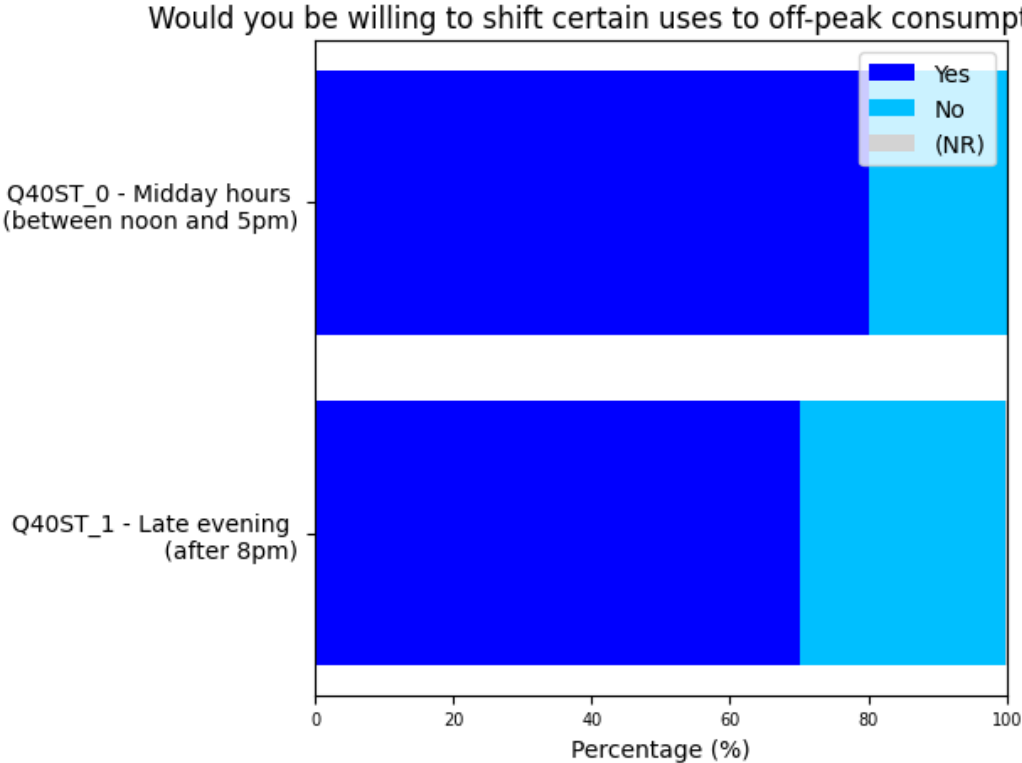


Figure 9. Percentage of acceptance for manual shifting at midday (Q40ST_0) and in the late evening (Q40ST_1)

Results from Chi-2

As discussed in the methodology section, the initial step of the empirical analysis involved chi-square tests of independence, conducted separately for each explanatory variable in relation to the two outcome variables.

As a reminder, a *chi-square test* compares the proportion actually observed in the survey with the expected proportion to establish if they are significantly different. In the chi-square test of independence, if the χ^2 corresponds to a p-value lower than 0.05, the null hypothesis of independence can be rejected (Onchiri, 2013), and the independent variable is considered as having an influence on the dependent variable.

The findings reveal that several variables exert a statistically significant influence on the willingness to manually shift electricity consumption. For Q40ST_0 these significant variables include gender, age, size of locality, socio-professional category, household income, type of dwelling, electricity contract, attitudes toward progress versus traditional lifestyle, measured room temperature, environmental

values, and trust in technology (**Table 13**). These results reflect the patterns reported in [section 4.2.1](#), where socio-demographic characteristics and moral values were identified in the literature as important determinants of flexibility-related behaviours.

The results for Q40ST_1, representing willingness to shift activities to late evening hours, reinforce this general pattern. Almost all variables tested display a statistically significant relationship with the outcome with only the exception of room temperature and sense of thermal comfort, which are not differentiating in this specific case. This suggests that while thermal comfort is relevant in some flexibility contexts, as emphasized by the structured literature review, it appears less decisive for evening shifts.

Table 13. Results of Chi² test of independence for Q40ST_0

Q40ST_0 - Would you be willing to shift certain uses to midday hours (between noon and 5pm)?										
Statistically significant influential variables										
	Gender	Age	Agglo size	CSP	Income	Dwelling type	Price scheme	Room temperature	Env values	TT / TW
Chi2	17.91638	46.45531	13.53301	59.68911	17.74912	8.113983	57.35279	21.90529	19.07191	13.75906
p-val	2.31E-05	2.4E-08	0.008945	1.09E-13	0.001381	0.017301	2.16E-12	0.000209	1.26E-05	0.001029
dof	1	6	4	2	4	2	3	4	1	2
Cramer's V	0.041868	0.067417	0.036387	0.076419	0.041672	0.028175	0.074908	0.046294	0.043197	0.049319
Non statistically significant influential variables										
	Household size	Children	Education	Ownership	Floor space	Supp heating	DPE	Thermal comfort	Heating control	
Chi2	8,449	1,402	1,316	1,767	5,962	2,107	6,342	1,901	2,421	
p-val	0,076449	0,236382	0,517776	0,413351	0,050731	0,146626	0,09611	0,386514	0,29806	
dof	4	1	2	2	2	1	3	2	2	

As discussed in the methodology part, the standardised residuals from the Chi-square test are used to understand the influence of a given explanatory variable.

Examining these results in relation to previous findings through the analysis of the standardised residuals, some confounding results can be highlighted.

Moreover, the influence of being at home mentioned in the literature is confirmed by the significant influence of both working from home (**Fig. 10**) and being inactive (**Fig.11**). The possibility to telework regularly is associated to a stronger willingness to shift during midday off-peak hours. The same is observed with socio-professional categories, where inactive people are more willing to shift than active individuals.

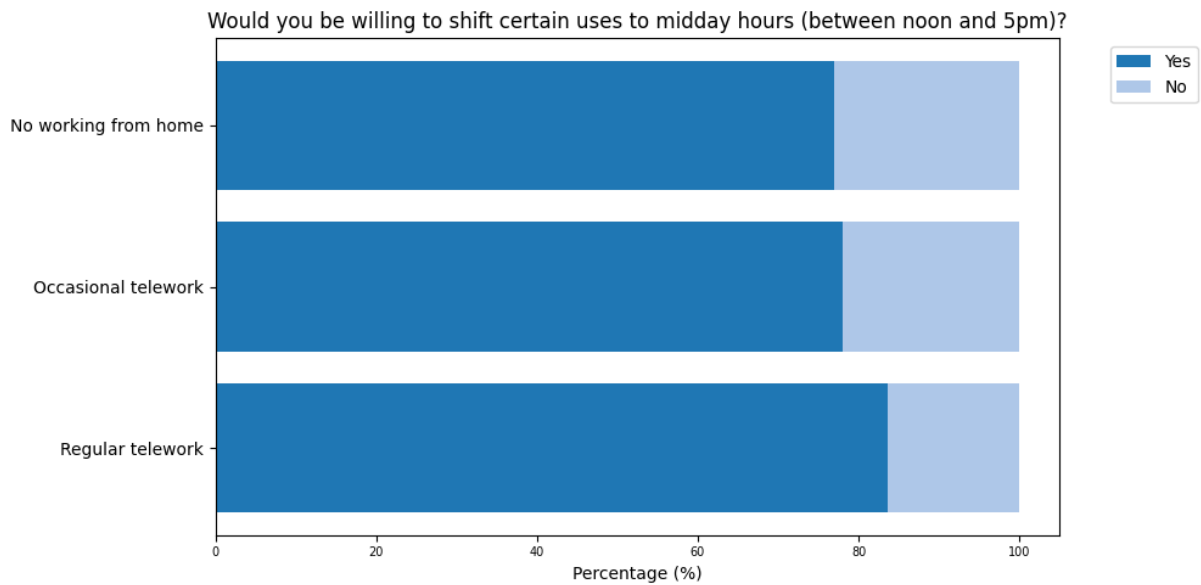


Figure 10. Willingness to shift to midday off-peak hours depending on telework

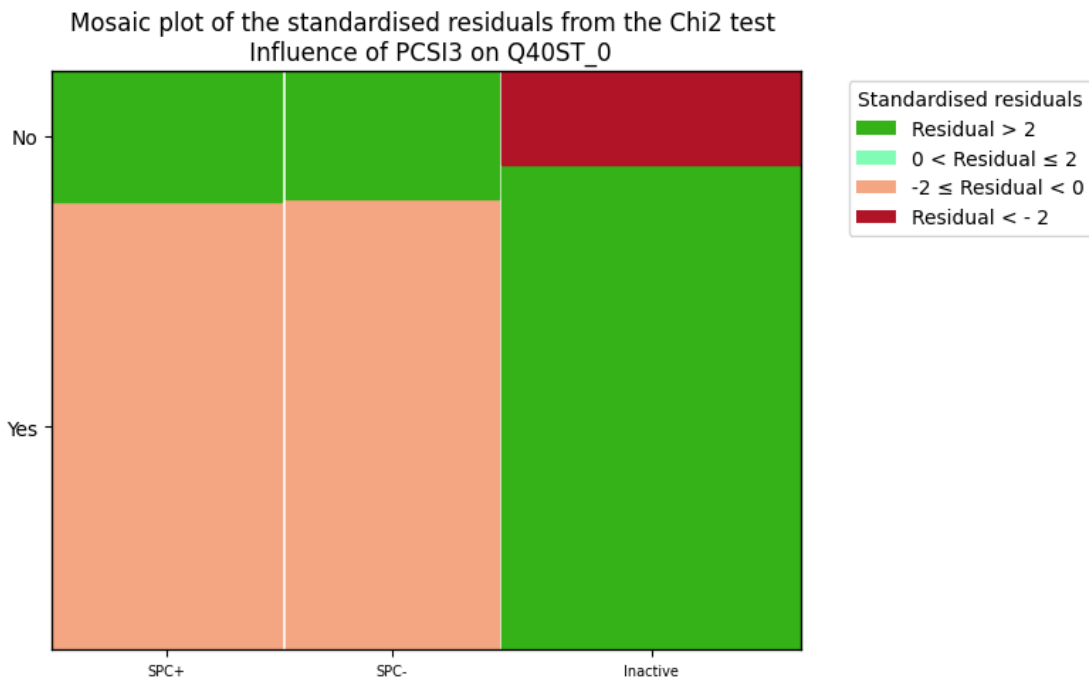


Figure 11. Mosaic plot showing the standardised residuals of Chi2 test for the influence of socio-professional categories on the willingness to shift activities to midday off-peak hours (IPSOs_2025)

However, some differences with the literature must be noted. In that sense, the influence of age is particularly noteworthy (**Fig. 12**). In the literature, older age groups are often described as less willing to adopt DSF practices, a trend observed for late evening shift. For willingness to shift usage to the late evening (Q40ST_1), respondents aged 75 and over are significantly more likely to oppose this shift, as indicated by standardized residuals greater than +2 for the “No” response. In contrast, the 18–24 age group demonstrates a significant under-representation among those opposed, with a standardized residual less than –2 for the “No” category, suggesting that younger respondents are less likely than others to reject shifting to late evening hours. However, for manual shifting during the day, the analysis of the Chi-2 residuals shows that people older than 65 years old are less likely to refuse. Conversely, respondents aged 65–74 are significantly more likely to express willingness to shift usage to midday,

as shown by standardized residuals greater than +2 for the “Yes” category. Finally, for the 35–44 age group, there is a significant over-representation of opposition to the midday shift, with standardized residuals exceeding +2 for the “No” response.

These results emphasize the importance of the temporal dimension in shaping acceptability of DSF, suggesting that preferences for shifting energy use are closely linked to the organization of daily routines, which vary significantly across age groups. These findings underscore the need to consider not only age, but also the specific timing of flexibility actions, as the organization of the day and associated constraints or opportunities differ markedly between younger and older respondents.

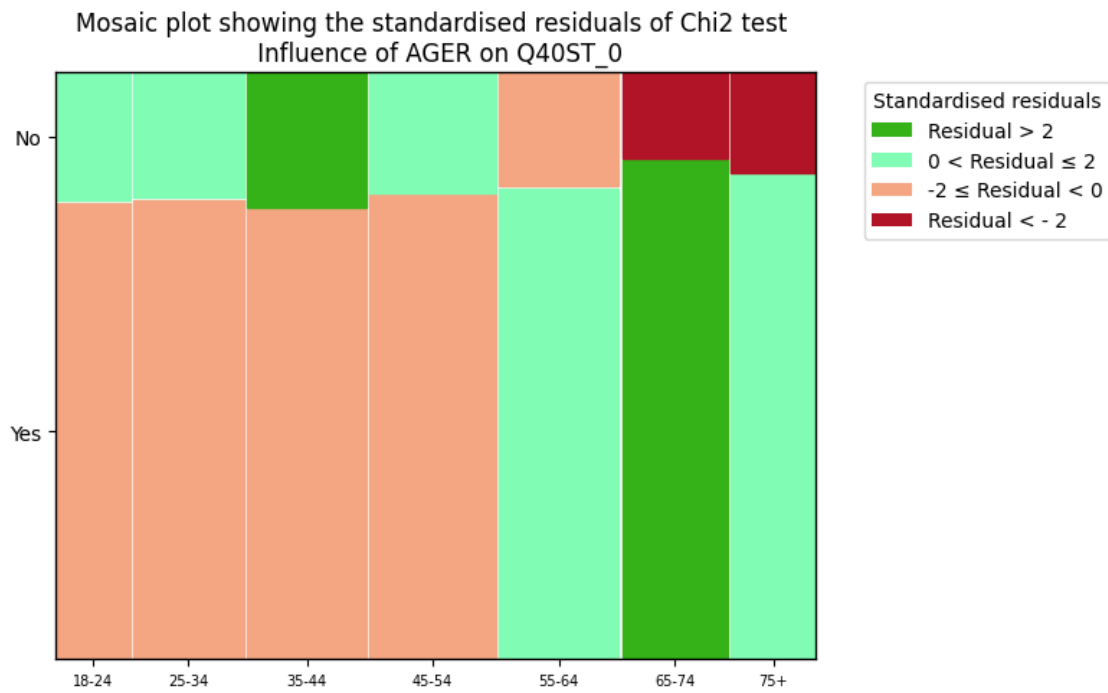


Figure 12. Mosaic plot showing the standardised residuals of Chi2 test for the influence of age on the willingness to shift activities to midday off-peak hours (IPSOS_2025)

Another difference with the literature is observed with income. Higher household income, associated with reduced motivation to participate in flexibility programs in the literature, is positively associated with acceptability of late-night shift (Fig 13). It may be due to a correlation between dwelling type and income, with living in a flat being associated to low income as visible in Figure 14. According to Li et al. (2017), people who lives in a flat experience more disturbance from noise of the appliances at night resulting in less willingness to shift some practices like dishwashing or laundry, especially at night. This is what we observed in the survey with people living in individual houses being more willing to shift uses to the late evening than others (Fig. 15).

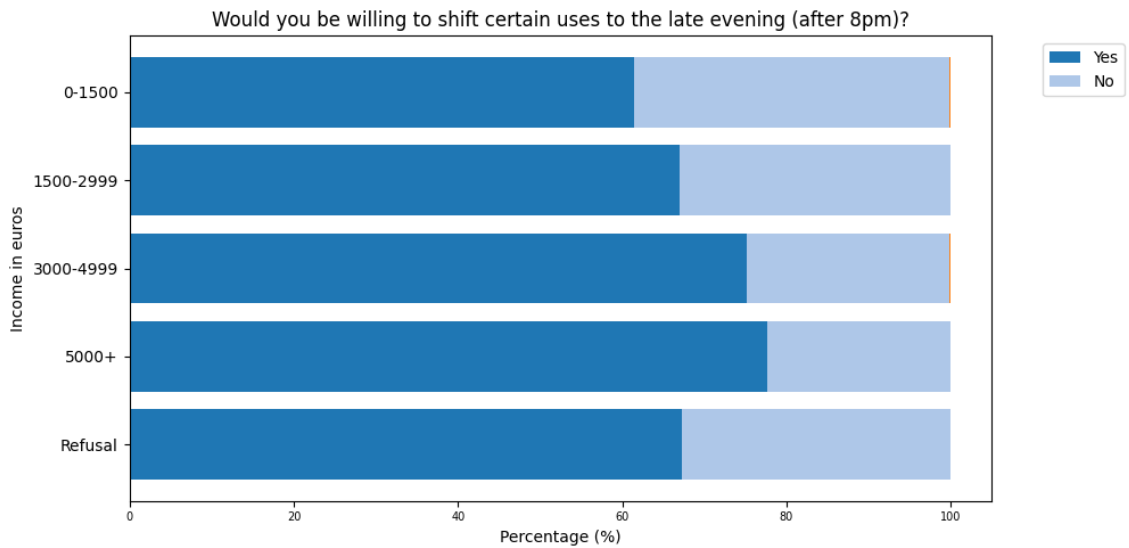


Figure 13. Willingness to shift to late evening depending on the income (IPSOS_2025)

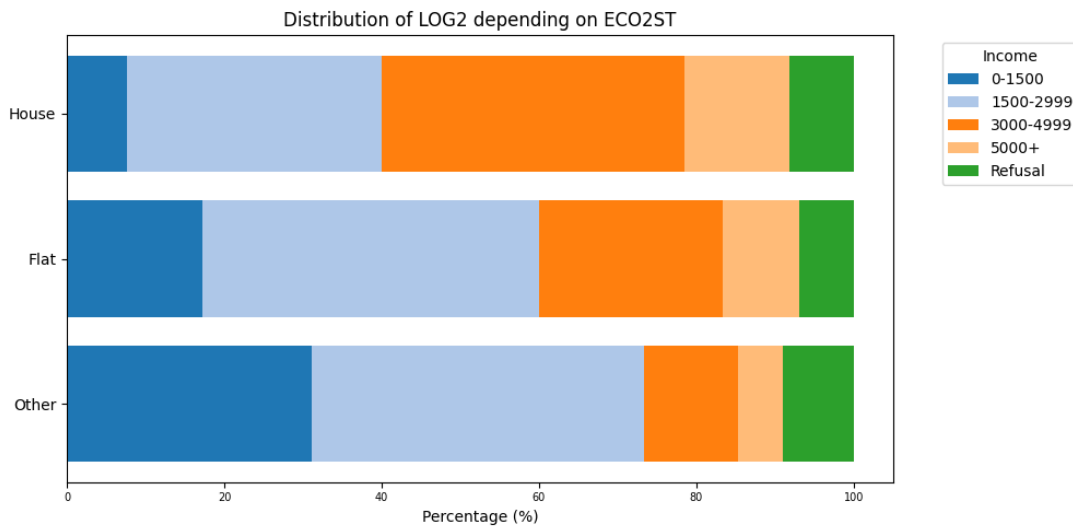


Figure 14. Relation between dwelling type and income (in euros) as a potential indirect effect explaining the higher acceptability for higher income (IPSOS_2025)

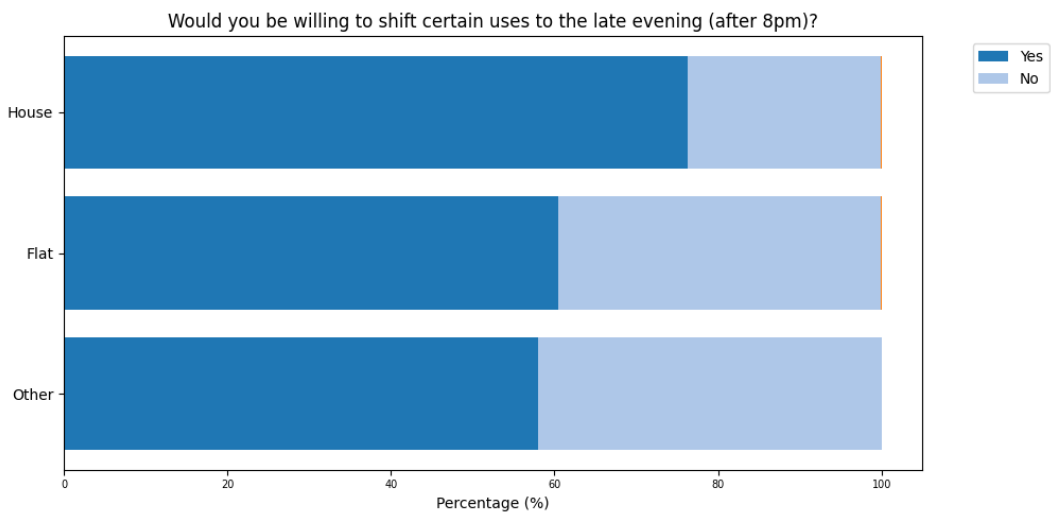


Figure 15. Willingness to shift to late evening off-peak hours depending on the dwelling type (IPSOS_2025)

Moreover, some variables found significant in the literature do not appear to have a strong effect in the French context, at least not for regular manual flexibility during midday hours. Notably, variables such as household size, presence of children, education level, and homeownership did not show statistically significant relationships with Q40ST_0 in the chi-square analysis. This absence of effect may reflect particularities of the French sample or indicate that certain household characteristics are less relevant when it comes to manual shifting during the day, which may be more related to the possibility to be at home during these hours.

Finally, despite the statistical significance of several variables, it is important to emphasize that the effect sizes obtained, as measured by Cramer's V, are uniformly small. This suggests that although certain factors are associated with differences in acceptability, none can be considered a strong determinant on their own. This observation is consistent with the literature's general depiction of DSF acceptability as a phenomenon shaped by interacting forces rather than by any single dominant driver.

Results from the multinomial logistic regression

Moving beyond bivariate relationships, the multinomial logistic regression analysis allows for an assessment of the simultaneous effect of all independent variables on the two outcome measures. These multivariate results provide an additional level of evidence regarding the relative importance and robustness of specific factors, especially when potential confounding influences are controlled for.

The regression results for Q40ST_0 (midday shift) indicate that age, environmental values, working from home, indoor temperature, type of tariffs, geographical area and gender remain significant predictors even when all other variables are accounted for (**Appendix 4**).

Notably, for Q40ST_1 (late evening shift), working from home is not an explanatory factor. The regression results indicate that the main predictor is the type of tariffs, followed by income, education, type of dwelling, gender, age, floor surface, thermal insulation, environmental values (**Appendix 5**).

It is worth noting that the significance and direction of these effects largely echo the findings from the chi-square tests, but the multivariate model provides greater nuance by allowing the isolation of each variable's unique contribution. Certain variables that did not attain significance in the bivariate analysis remain non-significant here, while others such as attitudes and values display persistent relevance even after socio-demographic and housing characteristics are controlled.

In this section, variables that influence social acceptability of DSF were identified for various categories of DSF using the structured literature review (section 4.2.1), with a focus on the French context for manual flexibility (section 4.2.2). The survey analysis highlights the importance of timing when it comes to manual shifting, with a higher acceptance to shift to midday hours than to shift to late night hours (**Fig. 9**).

For midday shift, the key findings are that regular telework and time varying tariffs are positive predictors of acceptability, as well as living in a medium to big agglomeration. A high indoor temperature has a negative influence of acceptability.

For late night shift, having a time-varying tariffs is a great positive predictor, with households being 5 times more likely to be willing to shift their practices to late night hours. High education, high income and floor surface over 120m² are positive predictors, while living in a flat and bad thermal insulation are negative predictors of acceptability.

4.3. Acceptability of manual shifting in France

A final step of the analysis is to answer **Q3**. How are different categories of flexibility actions perceived and accepted, and how do these perceptions vary according to the identified influencing variables?

First, manual shifting is quite developed in France for different uses. The current flexibility of households in France has been assessed for different appliances, among households who own these appliances (**Fig. 16**). As discussed in part 2, domestic water production is automatically turned on during off-peak hours, which explained the high number of positive responses (almost 70%).

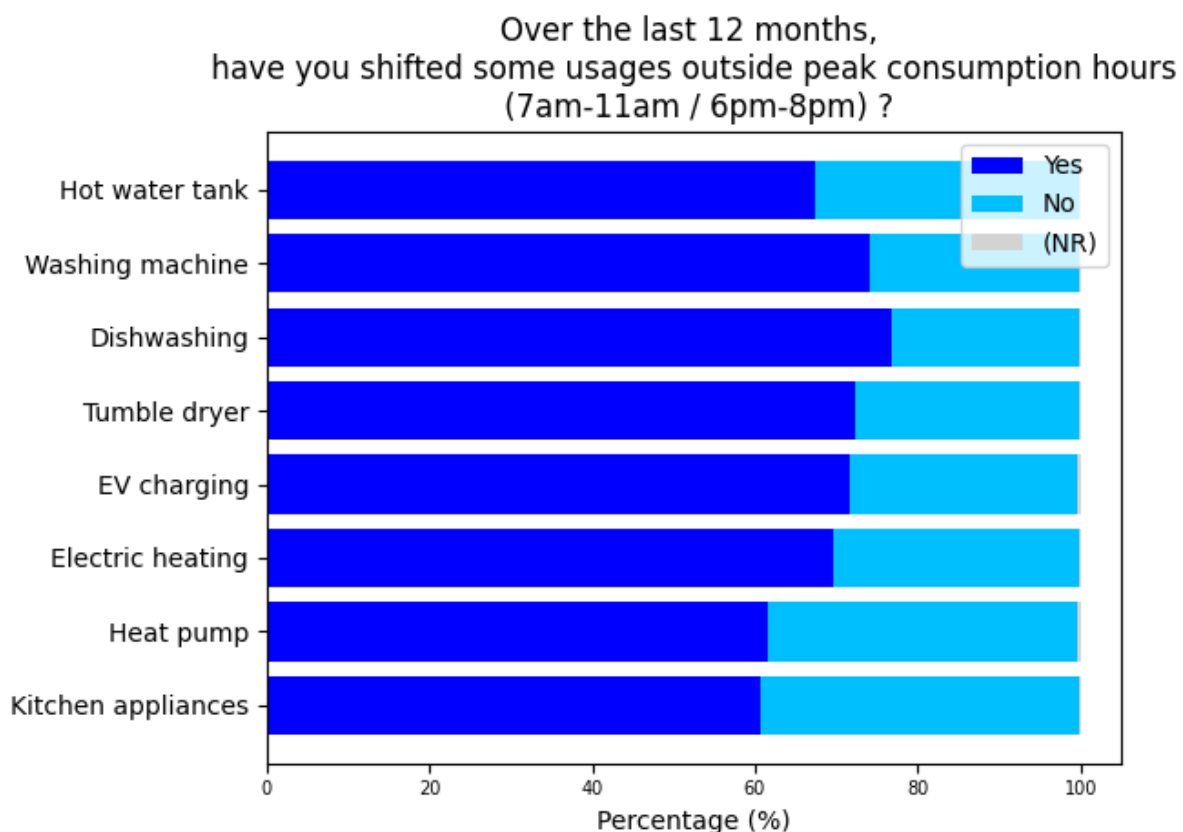


Figure 16. Flexibility in 2025 for different appliances (IPSOS_2025)

Moreover, using the survey, I studied the influence of the previously identified variables on the barriers and drivers, specifically for regular manual shifting (categories 1 and 3 of the framework – see **Table 3**). The same method as for the previous section was used.

The influence of the variables on the identified obstacles and motivations is represented in **Table 14**. Only the statistically significant variables are represented, with a blank being left for non-significant variables. The value corresponds to the odds ratio for the modality compared to the reference one.

Some interesting results can be highlighted. First, the influence of the tariffs is striking. Households with variable tariffs, whether regular or not, are significantly more likely to be motivated by the cost savings, and less by environmental benefits. The organisational constraints are also more likely for households with variable tariffs than for households with fixed tariffs.

Also, as discussed previously, living in a flat is more likely to come with organisational constraints (including noise) than living in an individual house. Households whose dwelling is not well insulated (DPE D,E) are more likely to mention organisational constraint and to be attracted by cost savings

compared to households with high thermal insulation. In terms of organisation, regular telework is also less associated to organisational constraints as a barrier to flexibility than no telework.

Regarding the obstacles to flexibility, the gender appears significant regarding both the economic and inconvenience barriers. The organisational constraints being more mentioned by women may be related to the fact that women are more in charge of domestic practices and organisation, as described by the concept of mental load (Costil, 2024).

According to Schöne et al. (2022), households with low electricity expenses (<80€ a month) are less interested by any other incentives than the economic benefits. In the survey, the more electricity expenses a household have the more they tend to be interested in cost savings. However, for the other incentives the variable is not significant.

As expected, households with high environmental values are motivated not by new habits but more by a reduction of greenhouse emissions.

While this analysis works for manual shifting, these findings could be cautiously generalised for the barriers and incentives more generally. Therefore, the categories where a barrier appears to be high would be less accepted by a population highly influenced by this given barrier. For instance, material issues are more present for tenants, which could mean more difficulties for them to engage with DLC or HEMS flexibility methods (**Table 9**).

Table 14. Household characteristics influencing barriers and incentives

Barriers / Incentives	Age	Electricity expenses	Gender Vs man	Education Vs no diploma	Income Vs <1500€	SPC Vs inactive	Dwelling type Vs house	Tariffs Vs fixed	Thermal insulation Vs high insulation	Thermal comfort Vs no cold	Indoor T° Vs 19°C	TW Vs no TW	Size Vs 1 person	Env values Vs no value	Tenant Vs owner	Geographic Area Vs rural
Organisation constraints	0.99		Woman 1.34**	Graduate + 1.26**	1500-3000€ 1.18* 3000-5000€ 1.23*		Flat 1.69**	Variable 2.71** Tempo 2.87**	DPE D,E 1.14*			Regular 0.71**		1.11*		
Not enough difference on off peak/on peak			Woman 0.86**	Graduate+ 0.80**			Flat 0.88*	Variable 1.47** Tempo 0.71*	DPE D,E 0.76**			Occas. 1.20* Regular 1.30*	2 people 1.17*			
Material	1.0*							Variable 1.52**		Regularly cold 1.25*			4 people 0.80*	1.14**	Tenant 1.25**	Big aggro 0.81**
Habits	1.0*			Graduate + 0.85**				Variable 0.59** Tempo 0.40**		Regularly cold 0.74**				0.81**		
Cost savings during off peak hours	0.99*	1.0**			1500-3000€ 1.26* 3000-4999€ 1.30*	SPC- 1.20*		Variable 10.82** Tempo 13.60**	DPE D,E 1.20*			Regular 0.73**	4 people 0.76**			Metropolis 0.79**
Reduce peaks where a lot of greenhouse gas are emitted	1.01**							Variable 0.79**			<19°C 0.75** 20-21°C 0.82*			1.60*		

4.4. Main findings

The aim of this study was to identify and understand the factors and mechanisms that determine the acceptability and development of demand-side flexibility (DSF) among French households, in order to inform strategies for increasing DSF adoption in the residential sector and facilitate modelling in future studies. To do so, I answered three research questions.

First, the social barriers that hinder demand-side flexibility among French households have been identified. For the automatic methods of flexibility, privacy concerns and need for new materials are the main obstacles for households. For the manual method, the disruption of habits and routines is a key barrier, together with inadequate tariffs. The social drivers that foster demand-side flexibility among French households have also been identified. The cost savings allowed by flexibility is the main one, followed by environmental benefits. Evolution of habits is also a key driver for manual flexibility.

Then, the households' characteristics that influence their acceptability of DSF have been studied. Socio-demographic factors, household structure and organisation, and values have an impact on their willingness to be flexible. Using the survey results, I found that the temporality of flexibility is important for manual flexibility with a higher acceptance to shift during the day than to shift during the night. The most influential variables also vary depending on the temporality. Spending time at home with regular telework is a positive predictor for shifting during the day while it does not influence the willingness to shift at night. Also, living in a flat is a negative predictor of the willingness to shift at night while it has no impact for midday hours.

Finally, the variations from one category of flexibility action to another were discussed. They are mentioned for the barriers and drivers. As discussed in part 4.3, some obstacles and incentives are explained by households' characteristics. For instance, living in a flat comes with more organisational constraint than living in an individual house. These findings can later be cautiously translated to assess the influence of a given variable for automatic categories of flexibility, even without a survey study. Concretely, if manual constraints are important for tenants, maybe tenants will have more difficulties to enrol in Direct Load Control programs or to manage their energy with a Home Energy Management System.

5. Discussion

5.1. Implications of the study

This study identified the factors that influence the acceptability of DSF for residential users in France.

Firstly, the barriers and drivers observed for France are consistent with the findings across Europe: inconvenience of manual shifting mentioned by Friis and Haunstrup Christensen (2016) and Öhrlund et al. (2019), as well as significant motivation from cost savings and environmental benefits, as described by many scholars (Caron and Durand-Daubin, 2016; D’Ettorre et al., 2022; Parrish et al., 2020; Pfeiffer et al., 2021).

Regarding household characteristics that influence acceptability, the results are consistent with those in the literature. As expected, based on the results of Li et al. (2020) and Parrish et al. (2020), being at home promotes flexibility during the day. The main predictors of flexibility in the evening are living in a house with ample living space. This replicates Li et al. (2020) and Schöne et al. (2022)’s findings on dwelling type, whereby flat dwellers are subject to more nuisances, particularly noise. The main difference with the literature concerns income. For evening flexibility, we observe a higher level of acceptability among high-income earners, which contradicts the results of Li et al. (2020) and Tomat et al. (2023). This can be explained by the observed correlation between high income, high education and favourable dwelling type.

The findings of this study have implications for public policy and the development of predictive models in the field of demand-side flexibility. By identifying the key barriers and incentives that influence household participation and highlighting the socio-demographic, attitudinal and contextual variables that most strongly impact flexibility acceptance, this research can support policymakers and energy providers in designing more effective, equitable and targeted interventions. Understanding which subgroups are most or least receptive enables communication strategies and contract offers to be tailored to address specific obstacles, such as inconvenience or trust in technology, and to maximise the appeal of incentives, particularly cost savings.

Furthermore, the comprehensive analysis of influencing variables provides a basis for enhancing quantitative models that aim to predict consumer response to flexibility measures. Integrating nuanced, empirically validated determinants into forecasting tools enables policy designers and grid operators to anticipate engagement and peak demand reduction patterns more accurately across different population segments. The distinction between midday and evening hours made in the study was not present in the literature and provides new insights for future public policies and models.

This study also involved the development of an analytical framework that distinguishes flexibility measures for households according to their temporality and level of automation. This framework enabled us to identify the main obstacles and drivers for the various flexibility categories. For forward-looking studies, this will make it possible to identify which categories of flexibility can be developed more easily, depending on which obstacles are overcome, or which incentives are made more accessible. For instance, facilitating access to enabling technologies, either economically or in terms of skills, could lead to greater uptake of automated flexibility. Similarly, taking into account households’ privacy concerns or adding the option to refuse flexibility requests could make flexibility offers more attractive to certain households. Overall, this framework allows for the refinement of prediction models for the electricity system. Indeed, it makes it possible to go beyond an overall ‘pool’ of flexibility to consider the specific characteristics of each flexibility action for households. In addition, it could be

used in future studies on flexibility to clarify the scope of the study or indicate specific characteristics according to category.

Overall, the study provides practical guidance on designing demand response programmes and methodological advances that strengthen the predictive capacity of energy behaviour models.

5.2. Limitations of the study

Several limitations should be acknowledged in relation to the present study. First, the empirical analysis is limited by the use of pre-existing survey data collected in May before my internship began; therefore, I had no input on survey design. This restricted the ability to include specific questions and may have resulted in gaps or insufficient detail. For example, the questions used to study the acceptability of a greater shift in electricity consumption practices were not differentiated by type of use. The distinction is studied in the survey only for the current development of flexibility. This prevents a certain nuance that was observed in the work of Li et al. (2020), regarding further development of flexibility.

The quantitative analysis also focuses solely on manual shifting of household electricity use in France, while other forms of demand-side flexibility (e.g., automation, direct load control) are addressed only through literature review due to the lack of relevant survey data. Moreover, because survey responses do not always reflect real behaviour (Öhrlund et al., 2019), the findings should be interpreted cautiously.

Another limitation of this study is the implicit assumption that the broader social context and organisation of daily life remain relatively constant. As the theory of social practices highlights, household energy demand and flexibility are deeply embedded in the socially constructed rhythms and routines that structure everyday activities (Shove et al., 2012). Significant shifts in social organisation, such as changes in work patterns, family structures, technological adoption or large-scale events affecting collective behaviour, could alter the timing, sequencing and flexibility of domestic practices. This could change the relevance or strength of the identified factors. Therefore, the applicability of the findings should be considered dependent on current social arrangements. Ongoing research is required to monitor and reassess these dynamics in response to evolving societal trends.

5.3. Suggestions for further work

First, the question of social justice could be examined more closely, especially considering that cost savings emerge as the main incentive for household flexibility. Recent literature highlights concern about both distributive and procedural justice in the context of smart metering and demand-side management (Milchram et al., 2018). Distributive justice relates to the fair allocation of costs and benefits: consumers often fear that they will bear the costs of new technologies without receiving evident advantages, whereas energy providers may profit disproportionately. There is also a fear from users that the responsibility for saving energy will be shifted onto them, while suppliers might neglect their role in ensuring affordable prices. Procedural justice concerns the fairness of decision-making processes and whether all stakeholders can participate meaningfully. Studies have shown that even when procedural justice is perceived as satisfactory, it does not automatically lead to greater acceptance or use of new devices (Milchram et al., 2018). These justice considerations highlight that, while economic incentives can motivate participation, fairness and trust are essential to the broad acceptance of demand-side flexibility schemes. Therefore, future research and policy should pay close attention to issues of equity and stakeholder involvement, to ensure the legitimacy and effectiveness of flexibility initiatives.

Also, future research should expand the analysis beyond manual flexibility to encompass a broader range of demand-side flexibility options in the French context, such as automated responses and direct load control mechanisms. By collecting or designing new surveys and empirical studies that address these additional forms of flexibility, researchers can develop a more comprehensive understanding of how households interact with different flexibility schemes.

Additionally, the survey captures perceived barriers for users without looking at how they respond in real-life situation. Future studies should incorporate evidence from pilot projects or field experiments to better assess real-world demand-side flexibility.

Furthermore, integrating these findings into quantitative models would enhance the ability to forecast the impacts of various demand-side strategies on electricity systems. Such models could simulate consumer responses and evaluate the potential for grid balancing, cost savings, and emissions reductions under different policy and market scenarios, ultimately providing policymakers and industry stakeholders with evidence for developing effective demand-side management programs.

6. Conclusion

This research set out to better understand the social mechanisms driving the acceptability and potential development of demand-side flexibility in the French residential sector. The analysis highlights how crucial it is to take into account the specificities of each flexibility measure, particularly their temporality, when considering their implementation or modeling. The survey and literature show that flexibility actions are not homogenous: the barriers and incentives associated with automated solutions differ substantially from those tied to manual actions, and the timescale of the flexibility measure also plays a determining role. This highlights the importance for future studies, as well as for policymakers, of not treating “flexibility” as a uniform category, but rather recognizing the diversity of practices encompassed.

The results also highlight the need to study the economic aspects of demand-side flexibility. Indeed, the prospect of achieving savings is a recurring factor for many households, and economic constraints are a significant barrier, particularly when tariffs or investment costs do not meet users' expectations. This duality requires a nuanced approach that takes into account not only technical realities, but also the economic realities of households.

Finally, by combining these insights, this work suggests new directions for forward-looking studies. Refinement of flexibility potential assessments will require a better integration of these social and economic factors, and should also consider how targeted public policies might overcome certain obstacles or enhance incentives. Similarly, the findings on households characteristics related to the acceptability of DSF emphasise the main variables to integrate in behaviour modelling such as home occupancy (working from home or being inactive), dwelling type, electricity price schemes, income. The findings thus contribute to a more granular understanding of residential flexibility, and can inform both modeling practices and the design of effective, user-centered energy transition policies. It also contributes to the currently scarce literature devoted to the French context.

Overall, promoting demand flexibility in the residential sector is not only a technical ambition, but also a social challenge. This study has shown the need to consider the time and economic constraints of households in order to develop appropriate flexibility options.

List of figures

Figure 1. Load curve change from (a) adjustable (b) curtailable and (c) deferrable appliances. In black the usual energy consumption and in red the change allowed by each type of flexibility (made by author).....	12
Figure 2. Diagram explaining the concepts surrounding demand-side flexibility (yellow) using real-life examples (white) – made by author	13
Figure 3. Methodological process to identify and assess the influencing factors of DSF acceptability	21
Figure 4. Process of the structured literature review	22
Figure 5. Barriers to shifting more uses to off-peak hours (IPSOS_2025).....	29
Figure 6. Main barriers to households' contribution to manual flexibility (IPSOS_2025).....	30
Figure 7. Survey results of incentives for a consumption outside of peak hours (IPSOS_2025)	34
Figure 8. Survey results for incentives (recoded) (IPSOS_2025)	35
Figure 9. Percentage of acceptation for manual shifting at midday (Q40ST_0) and in the late evening (Q40ST_1)	41
Figure 10. Willingness to shift to midday off-peak hours depending on telework.....	43
Figure 11. Mosaic plot showing the standardised residuals of Chi2 test for the influence of socio-professional categories on the willingness to shift activities to midday off-peak hours (IPSOS_2025)	43
Figure 12. Mosaic plot showing the standardised residuals of Chi2 test for the influence of age on the willingness to shift activities to midday off-peak hours (IPSOS_2025)	44
Figure 13. Willingness to shift to late evening depending on the income (IPSOS_2025)	45
Figure 14. Relation between dwelling type and income (in euros) as a potential indirect effect explaining the higher acceptability for higher income (IPSOS_2025).....	45
Figure 15. Willingness to shift to late evening off-peak hours depending on the dwelling type (IPSOS_2025)	45
Figure 16. Flexibility in 2025 for different appliances (IPSOS_2025)	47

List of tables

Table 1. Classification of electric uses depending on the load change and highlighting non-flexible uses (made by author).....	17
Table 2. Level of control over appliances (RTE et al., 2024).....	18
Table 3. Categories of DSF actions based on their temporality and their level of automation (made by author).....	19
Table 4. Key words search and their associated theme	21
Table 5. Search queries for Web of Science and Scopus.....	22
Table 6. Questions of the survey used as dependent variables in the analysis, to measure acceptability and current development of DSF (IPSOS_2025)	23
Table 7. Questions asked about barriers and drivers of DSF (IPSOS_2025).....	24
Table 8. Findings from the structured literature review on the barriers to DSF.....	29
Table 9. Level of barriers depending on the category of flexible sources for users (made by author). “No” means that the barrier does not apply to the category. The level of importance of the barrier for a given category is then visible through the colour distinction and the legend “Small”, “Medium”, “High”	32
Table 10. Summary of the structured literature review for motivation to DSF.....	34
Table 11. Incentives and drivers to DSF depending on the category of DSF actions (made by author).....	36
Table 12. Influencing variables to social acceptability of DSF identified in the structured literature review	40
Table 13. Results of Chi ² test of independence for Q40ST_0.....	42
Table 14. Household characteristics influencing barriers and incentives.....	49

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Appendices

Appendix 1. List of articles selected in the structured literature review

Reference	Method	Geographic area	Type of DSF	Uses
(Andolfi et al., 2024)	Survey	Luxembourg	Direct Load Control	Heating / EV charging
(Bender et al., 2024)	Survey (owners, with PV) / Stated choice experiment	Germany	Tariff types	Heating
(Broberg and Persson, 2016)	Choice experiment	Sweden	DLC	Heating / Broader domestic electricity
(Caron and Durand-Daubin, 2016)	Pilot project	France	Manual shifting: flexibility calls	Broader domestic electricity
(D'Ettorre et al., 2022)	Online Survey	France, Denmark, Italy, Spain	External control of the appliance: indicate the time by which the service must be accomplished	Laundry / EV charging
(Friis and Haunstrup Christensen, 2016)	Pilot project Interviews	Denmark	Manual shifting	Dishwashing, laundry, EV
(Li et al., 2020)	National survey MNLMs analysis to measure factors' influence	UK	Willingness to shift activities: none, early morning or late evening	Cooking, dishwashing, entertainment, heating, cloth-washing, showering
(Milchram et al., 2018)	Literature review	Europe, US	Acceptance of smart grid technologies	Not mentioned
(Öhrlund et al., 2019)	Interviews, activity-based diaries	Sweden	Price signals for manual shifting	
(Parrish et al., 2020)	Systematic literature review	UK, Europe, North America, Australia and NZ	Demand response	Not specified
(Pfeiffer et al., 2021)	Survey /User profiles	Austria	Home Energy Management System (HEMS)	Hot water production / Heat pumps
(Ruokamo et al., 2019)	Choice experiment	Finland	DLC	
(Schöne et al., 2022)	Survey - User profiles	Mayotte Island	DLC / Tariff types	Dryer, Dishwasher, Waterboiler, AC range, AC switch, EV, battery, PV
(Sridhar et al., 2023)	Survey	Finland	DLC motivations	Home appliances Heating EV (not based on ownership of EV)
(Srivastava et al., 2019)	Pilot program	Belgium	Effective shifting hours Acceptation of smart technology	HEMS, Smart appliances : washing machine, dishwasher and tumble dyers
(Tomat et al., 2023)	Survey	Spain, Italy, Greece, UK, US, Austria, Switzerland, Denmark, Irland	Acceptation of smart technology / Change of behaviour / DR programs	Cooking, laundry, ironing, dishwasher, air conditioning, EV
(Wen et al., 2025)	Survey	UK	Acceptability of different DSF programs (DLC, smart meter control)	EV charging, Heat Pump
(Yilmaz et al., 2019)	Control trial	Switzerland	Incentives for people to shift their consumption	

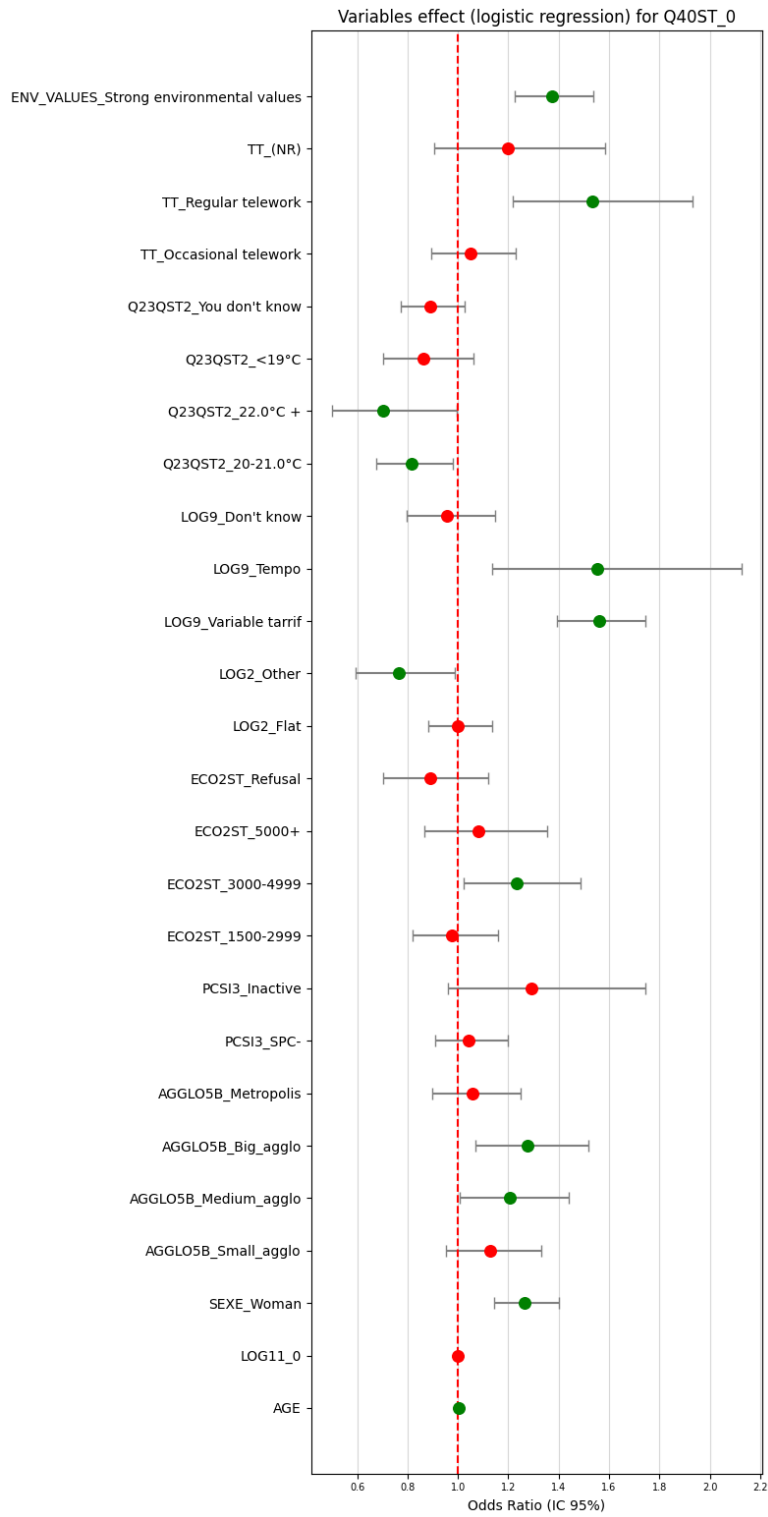
Appendix 2. Explanation of the variables

Variable	Definitions used in the already conducted survey	Categories
SEXE	Sexe / gender of the respondent	Man /Woman
AGE	Continuous variable: age of the respondent	
AGER	Age of the respondent recoded	18-24 / 25-34 / 35-44 / 45-54 / 55-64 / 65-74 / 75 years old +
AGGLO5B	Type of agglomeration	Rural (<2000 inhabitants) / Small_agglo (2,000-19,999 inhabitants) / Medium_agglo (20,000 -99,999 inhabitants) / Big_agglo (100,000-499,999 inhabitants) / Metropolis (500,000 inhabitants and more)
PCSI3	Socio professional category (SPC) following the French classification from INSEE and recoded	Inactive / SPC – (lower socio-professional categories) / SPC+ (higher socio-professional categories)
TT / TW	Telework	Regular telework (more than 3 days a week) / Occasional telework (from less than once a week to 2 times a week) / No telework
FOYST2	Household size	1 people / 2 people / 3 people / 4 people / 5 and more
KIDS18ST	Presence of children under 18 (still living with the family)	No child under 18 / Yes, at least one child under 18
EDUR3	Level of education	No diploma / High school diploma / Graduate and more
ECO2ST	Household income (after taxes)	<1500€ / 1500 – 2999€ / 3000-4999€ / 5000€ and more
LOG1ST	Ownership	Owner / Tenant
LOG2	Dwelling type	Individual house / Flat / Other (shared dwelling, ...)
LOG4ST	Floor surface	<60m ² / 60-120m ² / 120m ² and more
LOG8	Other source of heating	Yes / No
LOG 9	Type of tariffs	Fixed tariffs / Variable tariffs (on-peak / off-peak hours) / Tempo-like tariffs (dynamic variation: with selected peak days and on-peak/off-peak hours)
LOG10	Thermal insulation (following the French DPE indicator)	High insulation (DPE A,B,C) / Medium insulation (DPE D,E) / Bad to no insulation (DPE F,G)
LOG11_0	Electricity expenses per year (continuous variable)	
Q20	Thermal comfort during winter	Cold is not an issue / I am occasionally cold / I suffer regularly from the cold
Q22	Heating control: do you have a controller for your heater?	No (manual control on the appliance) / Yes, a connected thermostat / Yes, an unconnected programmable thermostat
Q23ST2	Indoor temperature: mean temperature of occupied rooms	<19°C / 19°C / 19.1-19.9°C / 20.0-21.9°C / 22.0°C and more / Don't know
ENV_VALUES	Environmental values based on the answer to the most pressing issues for France and how to reduce energy consumption)	Strong environmental values (fighting climate change or biodiversity or resilience to face climate natural disasters AND not answering “No need to reduce energy consumption) / No environmental values

Appendix 3. Descriptive statistics of respondents (IPSOS_2025)

Variable						
SEXE	Man: 47.8%		Woman: 52.2%			
AGER	18-24: 10.1%	25-34: 14.9%	35-44: 16.1%	45-54: 17.0%	55-64: 16.2%	65-74: 14.2% 75+: 11.5%
AGGLO5B	Rural: 21.2%	Small_agglo: 18.1%	Medium_agglo: 13.8%	Big_agglo: 16.7%	Metropolis: 30.2%	
PCSI3	SPC+: 31.0%		SPC-: 28.6%		Inactive: 40.3%	
FOYST2	1 person: 25.3%	2 persons: 37.8%	3 persons: 17.8%	4 persons: 13.4%	5 persons and more: 5.7%	
KIDS18ST	No child: 73.1%		Children: 26.9%			
EDUR3	No high school diploma: 21.6%		High school diploma: 24.9%	Graduate +: 53.5%		
ECO2ST	Less than 1500€: 14.2%	1500€-2999€: 37.1%	3000€-4999€: 30.9%	5000€ and more: 10.4%	Refusal: 7.4%	
LOG1ST	Owner: 59.8%		Tenant: 35.3%		Other: 5.0%	
LOG2	House: 58.7%		Flat: 37.2%		Other: 4.0%	
LOG4ST	<60m²: 19.3%	60-120m ² : 54.0%	>120m²: 26.6%	(NR): 0.1%		
LOG8	Yes: 36.9%		No: 63.1%			
LOG9	Fixed tariff: 46.2%	Variable tariff: 41.4%	Tempo like: 3.2%	Don't know: 9.2%		
LOG10	DPE A, B, C: 22.8%	DPE D, E: 20.0%	DPE F, G: 2.9%	You don't know: 54.3%		
Q20	Regularly cold: 14.9%	Occasionally cold: 40.7%	Cold not an issue: 44.4%	(NR): 0.0%		
Q22	Unconnected programmable thermostat: 38.4%	Connected thermostat: 13.6%	Manual control: 48.0%	(NR): 0.0%		
Q23QST2	<19°C: 9.7%	19°C: 16.9%	19.1-19.9°C: 0.0%	20-21.0°C: 11.8%	22.0°C +: 2.3%	You don't know: 59.3%
TT	No working from home: 34.2%	Occasional telework: 14.8%	Regular telework: 6.4%	(NR): 44.7%		
ENV_VALUES	No environmental values: 66.7%		Strong environmental values: 33.3%			

Appendix 4. Variables effect on acceptability of midday hours manual shifting



Appendix 5. Variables effect on acceptability of late evening manual shifting

