SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Behavioural insights for electricity demand flexibility

Barriers and enablers to behaviour change and engagement with smart energy services

SEAI Behavioural Economics Unit

Behavioural insights for policy: evidence review

Behavioural insights for electricity demand flexibility

Barriers and enablers to behaviour change and engagement with smart energy services

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Sustainable Energy Authority of Ireland

SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with the public, businesses, communities and the Government to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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Introduction

Ireland is undergoing a significant energy transition to meet its Climate Action Plan 2023 targets of halving greenhouse gas emissions by 2030 and achieving net-zero emissions by 2050. This transition presents challenges, including rising electricity demand due to the expansion of Large Energy Users, such as data centres, the electrification of homes and transport and the unpredictability of renewable energy sources like wind and solar. Combined, these factors place strain on the electrical grid.

Electricity demand flexibility, where energy users adjust their electricity consumption in response to supply fluctuations, offers a solution to alleviate grid strain, reduce emissions and accelerate the energy transition. Actions such as shifting appliance use to off-peak times and periods of renewable energy abundance, adopting technologies like solar photovoltaic installations (solar PV) and smart thermostats, participating in demand side flexibility programmes and switching to time-based tariffs (static time-of-use pricing and dynamic energy tariffs can all enhance flexibility and reduce emissions. This report will focus on the actions that households and Small and Medium Enterprises (SMEs), collectively referred to as energy users, can perform to enhance demand side flexibility.

Behavioural science can guide strategies to encourage participation in demand side flexibility schemes, adoption of smart energy technologies, and adjustments to daily routines. By leveraging these insights, Ireland's energy stakeholders can improve outreach efforts and move closer to the national demand flexibility target.

This report explores the various demand flexibility actions available to households and SMEs; outlines the pathways to implement them; examines the behavioural barriers they face; and presents a set of behavioural interventions and policy recommendations that are relevant to different stakeholders, including policymakers, Distribution System Operators (DSOs), regulators and energy providers.

Taxonomy of demand flexibility behaviours

There are a myriad of actions and behaviours that households and SMEs can adopt to adjust their electricity consumption to supply fluctuations. To effectively promote electricity demand flexibility, it is important to identify these behaviours, their characteristics, and their potential impact on the energy grid in a systematic way.

This report offers a taxonomy that maps out and classifies electricity demand flexibility behaviours according to several criteria: required frequency of action; the primary agent involved; costs, energetic impact; and behavioural and cognitive effort. This provides a behavioural framework for analysing demand flexibility behaviours and identifying strategies to encourage adoption by households and SMEs.

Priority behaviours to target

The most promising demand flexibility behaviours are those that require minimal effort and financial investment or resources while delivering a significant impact on the energy grid. However, the effort required and the potential for shifting electricity consumption depend largely on the technologies that energy users have. To account for this, we classify energy users in two groups: those without key demand flexibility technologies, who typically have lower electricity loads; and those who have technologies with higher electricity loads, such as electric vehicles (EVs) and heat pumps. This distinction underscores the need for tailored approaches based on user segments.

Promising behaviours for energy users **without** demand flexibility technologies:

- **Water heating:** Avoiding using electricity to heat water at peak times. Smart controls make this easier but are not necessary.
- **Laundry:** Avoiding tumble dryer use by air drying clothes; opting for colder washes and shifting laundry activity away from weekday peak periods.
- **Cooking:** Minimising the use of traditional ovens and opting for more energy-efficient alternatives like air fryers; preparing meals in advance by batch-cooking at weekends.

Promising behaviours for energy users **with** demand flexibility technologies:

- **Programme appliances to run off-peak:** Schedule the use of electrical appliances or integrate smart appliances with time-based tariffs to run during off-peak hours or times of electricity abundance. Timing of laundry, water heating, and dishwashing can be optimised through the use of time-programming appliance features.
- **Use solar-generated energy flexibly:** Align onsite consumption with solar PV generation, integrate the system with a home battery to store for use when most is needed, and sell any excess at optimal (high demand) periods.
- **Charge EVs during off-peak or times of clean energy abundance:** Integrate EV chargers with time-based tariffs or manually set specific charging schedules based on off-peak hours or times of electricity abundance. EV-specific tariffs with strong incentives are available, and for many people with an EV, scheduling the charging to occur at the right time should be relatively straightforward.
- **Run heat pumps during off-peak or times of ample clean energy:** Integrate heat pumps with time-based tariffs or manually set specific running schedules based on off-peak hours or times of electricity abundance.

Electricity demand flexibility roadmaps

This report also maps demand flexibility activities to help understand the steps households and SMEs take to shift electricity consumption patterns; engage with demand flexibility technologies; and participate in demand side flexibility programmes and time-based tariffs. These roadmaps also map the barriers that energy users experience at each step along these journeys, informing potential policy recommendations and interventions to boost engagement and increase participation.

The report presents detailed roadmaps for:

- **Behaviour change:** Peak shaving and shifting.
- **Demand flexibility programmes and services:** Tariff switching and demand side flexibility programme participation.
- **Demand flexibility technologies:** Adoption and flexible use of smart appliances, EVs, heat pumps, and solar PV systems.

Taken together, these roadmaps highlight the critical interdependencies between technologies and behaviours, offering a comprehensive yet flexible approach to achieving demand flexibility. They acknowledge differences among population segments and the different constraints they face, such as financial limitations. Instead of providing a single pathway, these roadmaps present a flexible framework that energy users can adapt based on their specific circumstances.

Some of the highest-priority solutions and policy recommendations outlined in these roadmaps are laid out in the tables below. Separate tables display recommendations for encouraging behavioural changes, adoption of time-based tariffs, participation in demand response programmes, and flexible use of smart appliances, heat pumps, EVs, and solar PV and stored energy. More recommendations are included in the full roadmaps in Section 3.

Behavioural changes

Policy recommendation
Educate energy users about the need for demand flexibility and the multiple benefits of reducing peak demand, including the environmental aspects.
Ensure that flexibility policy and measures directed at large energy users are communicated to the public. This is likely to increase perceptions of fairness, which are particularly important in household flexibility intentions.
Help energy users understand which appliances use the most electricity by developing in-home displays and apps with real-time feedback to help people visualise savings and build a better understanding of the key activities to change.
Target behaviours that are easy to shift, such as scheduling dishwashers and washing machines; scheduling the charging of EVs; and sometimes substituting an air fryer for an oven, or batch-cooking.
Improve financial incentives for peak shifting by sculpting tariffs that make peak and off-peak rates more financially distinct. Make feedback and financial rewards more immediate (for example, visible on the next energy bill).
Incorporate gamification to in-home displays and apps. Include elements such as goals, weekly energy saving challenges, and a sense of progression to motivate energy users.

Demand flexibility programmes and services

Policy recommendation
Time-based tariff adoption and alignment
Provide simple, consistent communication about how time-based tariffs work using decision trees, simple tables listing peak and off-peak prices, and FAQs.
Standardise tariff naming and terminology. More consistent naming across all energy providers and public service bodies would reduce consumer confusion.
Introduce an education process for customers before they enrol in time-based tariffs to ensure they understand the risks and benefits.
Promote development of standardised consumer tools that are easily integrated with smart meter data (for example, tariff comparison websites) to help customers make informed choices about time-based tariffs.
Reduce the risk associated with switching using trial periods or price guarantees.
Demand response programme participation
Address concerns about privacy and trust. Providing data security assurances helps build trust and mitigate data concerns. Consider mandating providers to display real-time information on when and how devices are controlled.
Address concerns about loss of control. This can be done through emphasising the ease of device override and providing direct load control programmes that are easy to opt out from.
Offer smart home appliances that have been pre-enrolled to direct load control. The sale of pre-enrolled devices can be supported by purchase discounts, bill credit bonuses, and easy-to-opt-out direct load control programmes.

Provide meaningful financial incentives and market frameworks for energy users to participate in demand side flexibility programmes.
Implement mechanisms to verify real actions taken by customers during demand response requests rather than relying solely on self-reported behaviour.

Demand flexibility technologies

Policy recommendation
Smart appliances
Incentivise smart enabled appliances to help enable flexibility particularly for energy users whose routines are less flexible, like families, full time workers and those with caring responsibilities.
Educate retail salespeople on the flexibility potential and associated savings of smart appliances. In their capacity as sources of expertise at the point of purchase, this may help to increase the uptake and subsequent flexible use of smart appliances.
Ensure interoperability standards between smart appliance manufacturers and energy providers. Mandate manufacturers to adhere to interoperability standards such as the Code of Conduct for Energy Smart Appliances.
Standardise real-time feedback provided by smart appliances and in-home displays.
Create user-friendly dashboards for smart appliances with visual cues, such as colour-coded indicators of energy consumption.
Heat pumps
Run nationwide targeted campaigns to address misconceptions about heat pumps and highlight benefits, such as comfort and long-term savings.
Educate installers and encourage provision of flexibility information and advice during heat pump installation.
Offer greater subsidies and trial opportunities, particularly for vulnerable households.
Implement performance-linked financial incentives that reward participation in heat pump demand side flexibility programmes, such as energy bill rebates.
EVs
Promote the additional savings available through EV-specific tariffs. EV dealers can educate prospective buyers and promote optimal EV charging.
Introduce regulation to mandate that EV chargers have smart functionality.
Forefront range information in mileage rather than battery percentage or kWh, and tailor information based on individual driving profiles.
Emphasise the environmental benefits of the transition to EV at each stage to promote positive spillover effects, such as flexible charging post-EV adoption.
Programme EV chargers to operate outside peak hours by default.

Solar PV
Provide grants and subsidies specifically aimed at low-income households to promote equitable access to solar PV installations.
Develop specific policies for solar PV adoption in multi-unit residential buildings, such as shared PV systems for apartments.
Promote battery storage as a key component of solar PV investments including by expanding SEAI's grant programs to provide incentives to install both.
Introduce specific tariff structures that benefit customers who use battery storage alongside solar PV systems, optimising their energy costs and promoting self-consumption.
Integrate provision of demand flexibility information into the grant approval process and installer training programmes so that people are aware of how best to use their new technology to the benefit of the grid and themselves.

Conclusion and future directions

Electricity demand side flexibility is necessary to manage rising electricity demand and renewable energy integration. This report outlines strategies to encourage households and SMEs to participate in energy-saving or shifting behaviours, smart technology adoption and flexible use, and participation in time-based tariffs and demand response programmes. These strategies and policy recommendations are relevant to policymakers, DSOs, regulators, and energy providers. They make clear the need for coordinated action on multiple levels: improved awareness and communication (for example, educating energy users about their role in demand response through targeted campaigns); simplification (for example, streamlining smart tariff offerings to make them more accessible and user-friendly); incentivisation (for example, offering discounts on purchasing smart appliances pre-enrolled in demand response programmes); infrastructure development (for example, enhancing the interoperability of smart appliances and home energy management systems); and community engagement (for example, building networks to connect prospective low-carbon technology buyers with existing owners). By implementing these recommendations, policymakers can empower Irish energy users to actively participate in the energy transition, contributing to grid stability, reduced emissions, and lower energy costs.

Alongside these recommendations, the review points towards areas for future research or investigation. For example, greater understanding of the optimal mix of incentive types and structures to ensure flexible habits are sustained is needed. The extent to which people will engage in flexibility for non-financial reasons, such as care for the stability of the grid, resources, and the environment is equally important. We know perceived fairness is important for engagement, but further work to map out equity and distributional effects of different schemes is essential. For example, for vulnerable consumers, what are the most effective supports to increase flexibility capacity? High-use consumers disproportionately affect grid stability—interventions that specifically target these consumers are required.

There are also socio-technical questions in need of further attention. For example, how to deal with the high level of heterogeneity in heat pump set-up in the context of demand flexibility, where automated remote control can cause reduced comfort without simple solutions. How will users in Ireland engage with vehicle-to-grid when available? And how can solar PV owners be encouraged to maximise self-consumption during solar generation hours instead of feeding excess power into the grid, particularly during periods of grid overload? Moreover, what are the most effective incentives to promote joint solar PV and battery installations?

Several other open questions or factors in need of future research are laid out in the various "future directions" sections throughout the report.

1. Introduction

Ireland is undergoing a major energy transition. In its Climate Action Plan 2023, the Department of the Environment, Climate and Communications has set out to halve Ireland's greenhouse gas emissions by 2030 and to reach net zero no later than 2050 (Department of the Environment, Climate and Communications, 2023). The transition brings about several challenges. First, the overall demand for electricity increases, which is driven primarily by the expansion of large energy users such as data centres and industrial facilities. Alongside this, households and businesses are electrifying their homes (for example, by switching from gas boilers to heat pumps) and moving to electrified means of transport (for example, by switching from petrol-fuelled cars to EVs). Second, shifting to renewable energy sources, such as offshore wind and solar, makes the electricity supply less predictable. Lower predictability of supply combined with increased demand puts considerable strain on the electrical grid.

One way to reduce the grid strain is to increase the capability (and willingness) of energy users (both households and SMEs) to respond to the fluctuations in supply by altering their demand—a behaviour commonly referred to as demand flexibility. The SME and residential sectors offer significant flexibility potential. For example, Irish households alone account for about 50% of electricity demand during the evening peak of 5 pm to 7 pm (EirGrid, 2022). Demand flexibility in this sector can take different forms, from EV owners purposefully charging their vehicles overnight (when the energy supply is higher) and households shifting the use of energy-intensive appliances such as ovens, dishwashers, and washing machines away from peak periods to off-peak times. Energy users' flexibility capability can be further increased if they adopt technologies that enable time-based pricing, load shifting, and automation, such as smart meters, smart thermostats, solar PV with home battery storage systems, and heat pumps paired with smart controls and time-of-use tariffs.

1.1. Current progress in Ireland

The National Smart Metering Program has made significant progress in deploying smart meters across Ireland, paving the way for smart tariffs and demand side responsibility programmes. Over 1.9 million smart meters have been installed to date, with a full national rollout expected by the end of 2025. This deployment is an important enabler of demand response, in theory allowing consumers to track energy consumption in real-time (though real-time feedback is not yet available to customers in Ireland) and participate in flexible pricing programmes such as time-of-use (ToU) and dynamic tariffs. Tariffs that have different rates at different times of day come in many forms and often described using different names. In this report, we will use the term *time-based tariffs* to refer to this class of non-standard pricing schemes.

To support adoption of time-based tariffs, the Commission for Regulation of Utilities (CRU) introduced "Time-of-Use Primers" in 2019 to educate consumers on the benefits of these tariffs and how to effectively manage their energy usage. Supported by the substantial smart meter rollout, all major Irish energy providers offer static time-of-use tariffs and are mandated to offer dynamic tariffs by 1 June 2026. SEAI runs initiatives to improve public awareness about time-based tariffs and offers various grant programmes to encourage the adoption of demand flexibility technologies among households and SMEs. For residential properties, the National Home Energy Upgrade Scheme and the Better Energy Homes Scheme provide grants for energy efficiency upgrades, including heating controls and solar systems, which can significantly increase households' flexibility capital, though battery storage is not currently supported. For businesses, SEAI's Business Grants support energy efficiency projects that can contribute to demand response capabilities. These grants assist organisations in implementing measures such as energy monitoring and control systems, facilitating more responsive energy consumption patterns.

To reduce energy demand during critical peaks, ESB Networks (ESBN) piloted *Beat the Peak,* a scheme encouraging residential and commercial customers voluntarily limit consumption during two-hour periods, typically between 5 PM and 7 PM. The *Is This a Good Time?* awareness and engagement campaign now aims to align household energy use with periods of lower demand or higher renewable energy availability through prompts and rewards. Similarly, *Beat the Peak Commercial* campaigns ran in winter 2022 and summer 2023, and the re-launched version—*Beat the Peak Business*—has, since November 2023, invited organisations to commit to specific actions to reduce energy consumption during peak times, and rewards them for doing so.

1.2. Applying behavioural insights to unlock greater flexibility

As Ireland progresses toward its 2030 and 2050 energy targets, enhancing demand flexibility will be crucial for maintaining grid stability and optimising the use of renewable energy sources. The Commission for Regulation of Utilities (CRU) highlights citizen engagement as a key driver of flexibility in its National Energy Demand Strategy (CRU, 2024).

Insights from behavioural science can inform effective citizen engagement in demand flexibility. Specifically, behavioural insights can be applied to develop taxonomies of consumer flexibility behaviours and identify touchpoints and intervention strategies to encourage electricity demand flexibility. Applying these insights, Irish regulators, energy system operators, and energy providers can improve the effectiveness of their citizen outreach initiatives, getting closer to the 20-30% national demand flexibility target for 2030 (Department of the Environment, Climate and Communications, 2023).

This report presents a taxonomy of demand flexibility behaviours and seven demand flexibility roadmaps to assist policymakers with understanding the behavioural pathways to flexibility among Irish households and SMEs. The taxonomy and roadmaps were developed on foot of a review of academic and grey literature, as well as expert interviews with a range of stakeholders in Ireland. A detailed account of methods used for these reviews and interview structures is included in the Technical Appendix. The report is structured as follows. Section 2 introduces a behavioural taxonomy designed to provide an overview of different behaviours related to demand flexibility. Specific roadmaps for flexibility technologies, services, tariffs and behaviours are then presented in Section 3. Section 4 concludes the report. Additional materials are provided in the Technical Appendix that is presented separately.

2. Behavioural taxonomy

2.1. Introduction

In this section, we present a taxonomy that classifies various energy demand flexibility behaviours falling under the following three categories:

- Behavioural changes
- Engagement with demand flexibility programmes and services
- Uptake and flexible use of demand flexibility technologies

These behaviours are classified according to the following six criteria:

1. Frequency
2. Agent
3. Behavioural effort
4. Cognitive effort
5. Financial cost
6. Energetic impact

This taxonomy provides a behavioural framework for systematically analysing flexibility behaviours. Its purpose is to help prioritise behaviours to target, based on their potential for change and their impact on the energy grid. Additionally, the criteria selected for classification can guide the development of strategies to encourage adoption by energy users, as they are factors that often influence the design of behavioural interventions.

While all three categories of behaviour apply to both households and SMEs, the first—focused on behavioural changes—is more relevant to households, as it pertains to household activities. In contrast, the behaviours related to demand flexibility programmes and services and technologies are applicable to both households and SMEs.

2.2. Demand flexibility behaviours

A total of 63 demand flexibility behaviours were identified through a review of existing literature. Here we summarise and categorise the different types of behaviours identified. The individual behaviours involved are outlined with greater granularity in the Technical Appendix.

2.2.1. Behavioural changes

The first set of behaviours includes a variety of actions that enable energy users to adapt their electricity consumption to a fluctuating energy supply and reduce their consumption at peak times. Some of these involve an absolute reduction in consumption (i.e. shaving):

- Avoid electricity use (for example, air dry laundry).
- Minimise frequency or extent of activities (for example, cook in batches, run the washing machine with full loads).
- Replace energy-intensive activities (for example, use an air-fryer instead of a conventional oven).
- Change the duration of activities (for example, take shorter showers).
- Use shared spaces and appliances to reduce overall consumption (for example, spend time in public spaces in the evening).
- Use efficient settings on appliances (for example, use eco mode on appliances).

Other behaviours involve changing only the timing of consumption (i.e. shifting):

- Programme appliances to run off-peak (for example, programme washing machine/dishwasher to run at night).
- Manually shift the use of appliances to off-peak (for example, shift cooking to off-peak times).

2.2.2. Engagement with demand flexibility programmes and services

The second set of behaviours focuses on engagement with demand flexibility services and programmes. Some of these are related specifically to engagement with energy tariffs:

- Sign up to a time-based tariff.
- Optimise consumption for a time-of-use tariff.
- Optimise consumption for a dynamic tariff.

Others are related to engagement with other types of demand flexibility programmes:

- Sign-up for voluntary demand reduction events (for example, ESBN's *Beat the Peak*).
- Participate in voluntary demand reduction events.
- Enrol in direct load control programme.

2.2.3. Uptake and flexible use of demand flexibility enabling technologies

The third set of behaviours focuses on technologies that enable demand flexibility. On the one hand there are behaviours related to the adoption of these technologies in the first place:

- Install a smart meter and in-home display.
- Adopt smart appliances (for example, smart heating controls).
- Adopt a heat pump.
- Adopt an EV with a home charger.
- Install solar PV.
- Install home battery storage.

The flexibility potential of these technologies is then reliant on behaviours related to their flexible use:

- Integrate appliances with smart energy management systems.
- Monitor energy consumption and costs using in-home displays.
- Align smart appliance settings to price signals/grid emissions.
- Run heat pumps off-peak or at times of clean energy abundance.
- Charge EV off-peak or at times of clean energy abundance (manually or by integrating charger with time-based tariffs).
- Use solar generated energy flexibly (aligning with own consumption; providing surplus to grid during peaks).

2.3. Classification criteria

The behaviours in the taxonomies are classified using a set of criteria developed through a literature review and chosen for their practical relevance in designing behavioural interventions. Specifically, these criteria are commonly used to determine the most suitable type of behavioural intervention for a given behaviour. Further detail on each of the six criteria is given below.

2.3.1. Frequency

Frequency refers to the rate at which an energy user is expected to perform a specific behaviour.
This criterion includes three different categories:

1. **One-off:** These are actions that energy users only need to perform once, such as signing up for a service, adjusting appliance settings, or purchasing and installing a technology.
2. **Recurrent:** These behaviours occur repeatedly but with inconsistent frequency, as they are influenced by external factors. Their occurrence is often shaped by seasonal changes, market fluctuations, or exceptional circumstances.
3. **Habitual:** These are recurrent behaviours at more regular intervals, making them more likely to become habitual. These include daily activities, for example, minimising the use of ovens or delaying the use of dishwashers.

2.3.2. Primary agent

Energy demand flexibility arises from the actions of various agents, including energy users, energy providers, and appliances. It's important to note that in most situations, demand flexibility behaviours require effort from most of these actors in conjunction. For the sake of classifying behaviours, this was simplified by considering whether the bulk of the action of shifting or shaving energy consumption during the day is attributed to the energy user, an appliance or an energy provider. For this criterion, behaviours were then classified into one of the following three categories:

1. **User:** Energy demand flexibility is the direct result of behaviour performed by the energy user.
2. **Appliance:** Energy demand flexibility is the result of an automated action of an appliance or is mostly attributable to the automated functionalities of an appliance.
3. **Energy provider:** Energy demand flexibility is mostly the result of an action performed by the energy provider or a third party.

2.3.3. Behavioural effort

Flexibility-providing behaviours require varying levels and types of behavioural effort or input from energy users relative to what they may otherwise have done. Types of behavioural effort are investment of additional time, physical effort, disruption to habit, routine, or lifestyle, and emotional impact or reduced comfort. Behaviours were given a behavioural effort score (low, moderate, or high), based on the number of behavioural effort factors that they usually entail, over and above what people would likely do otherwise. While this criterion follows a clear protocol, it's important to note that it might not apply uniformly to all individuals. Five factors were considered:

1. **Time investment:** The time to prepare or perform the action, which might conflict with other priorities.
2. **Physical effort:** The manual effort involved in performing the action.
3. **Habit disruption:** The effort involved in breaking existing habits and establishing new routines.
4. **Emotional impact:** Frustration, uncertainty or stress associated with performing the behaviour, especially if results are not immediately apparent.
5. **Reduced comfort:** Performing the behaviour affects personal or household convenience and satisfaction.

2.3.4. Cognitive effort

Flexibility behaviours also require varying levels of cognitive effort. In many cases, separating what is cognitive from what is behavioural is not straightforward or even possible, but the factors included in this dimension require more substantial deliberation. Behaviours were again given a score (low, moderate, or high), based on the number of cognitive factors that they usually entail relative to what would otherwise be done. Five factors were considered:

1. **Action planning:** The need to plan when and how to perform the behaviour.
2. **Specific knowledge and skills:** Understanding what actions consume the most energy, available grants and programmes, or operating appliances effectively.
3. **Technical complexity:** The difficulty of using or reconfiguring technologies, applying to grants and programmes, or assessing the suitability of appliances and contractors.
4. **Attention demand:** The mental focus required to monitor and manage energy use.
5. **Social coordination:** Aligning behaviours with household or workplace members to avoid inconvenience.

2.3.5. Financial cost

Behaviours can involve varying levels of financial cost. In the longer term, all actions in the taxonomy can reduce costs and save money. This dimension is specific to the implementation of initial change. The categories are:

1. **Possible savings:** Performing the behaviour may enable the energy user to save energy, and by extension money from the start. However, the opportunity to save money may depend on the energy tariff they have.
2. **None:** No direct financial cost is incurred by energy users.
3. **Low:** Costs the energy user between €1 and €300.
4. **Moderate:** Costs the energy user between €300 and €3,000.
5. **High:** Costs the energy user more than €3,000.

2.3.6. Energetic impact

The effectiveness of behaviours in reducing or shifting peak energy consumption, assuming a constant energy load, can vary significantly. Behaviours are classified based on their energetic impact as:

1. **Low:** Results in a change in consumption of 200 kWh per year or less, equivalent to 0-5% of the average annual energy use of an Irish household.
2. **Moderate:** Results in a change in consumption between 200 kWh and 1,500 kWh per year, equivalent to 5-36% of the average annual energy use of an Irish household.
3. **High:** Results in a change in consumption over 1,500 kWh per year, equivalent to more than 36% of the average annual energy use of an Irish household. Notably, demand flexibility behaviours with a high energy impact are typically linked to technologies with high electricity consumption. As a result, their relative impact on a user's total electricity load may be lower.

2.4. Simplified taxonomy

The following three tables provide an overview of energy demand flexibility behaviours and outline their key characteristics. The first table examines behavioural changes undertaken by individuals to modify their energy use. The second explores behaviours related to participating in demand flexibility services, such as time-based tariffs and demand side flexibility programmes. The third focuses on adopting and using technologies in a flexible way.

Detailed versions of these taxonomies can be found in the Technical Appendix. They provide a nuanced breakdown of each behaviour.

Table 1: Behavioural changes

Sub-category	Behaviour [1]	Frequency	Primary agent	Behavioural effort	Cognitive effort	Financial cost	Energetic impact
Reduce load (peak shaving)	Avoid electricity use	Habitual or recurrent	User	Low to High	Low to Moderate	Possible savings	Low to Moderate
	Minimise frequency or extent of activities	Habitual or recurrent	User	Low to Moderate	Low to Moderate	Possible savings	Low to Moderate
	Replace energy-intensive activities	Habitual	User	Low to Moderate	Low to Moderate	Possible savings	Low to Moderate
	Change the duration of activities	Habitual	User	Low to Moderate	Low	Possible savings	Low to Moderate
	Use shared spaces and appliances	Habitual	User	Moderate	Low to Moderate	Low	Low to Moderate
	Use efficient settings on appliances	Habitual	Appliance	Low to Moderate	Low	Possible savings	Low to Moderate
Time-shift load (peak shifting)	Programme appliances to run off-peak	Habitual or recurrent	Appliance	Low	Low to Moderate	Possible savings	Low to Moderate
	Manually shift the use of appliances to off-peak	Habitual	User	Low to Moderate	Low to Moderate	Possible savings	Low to Moderate

[1] Note that each of the behaviours in this simplified version of the taxonomy is composed of multiple more specific behavioural actions. In many cases, these differ to each other in terms of required effort, cost, and energetic impact. That is why the table includes range-style values across low, moderate, and high. The colour used indicates which of the levels applies most broadly within the category. Green denotes low effort or cost, yellow is moderate, and red is high. While for energetic impact, red is low, yellow is moderate, and green is high. Detailed versions of taxonomies with all 63 specific behavioural actions are in the Technical Appendix.

Table 2: Engagement with demand flexibility programmes and services

Sub-category	Behaviour	Frequency	Primary agent	Behavioural Effort	Cognitive Effort	Financial Cost	Energetic Impact
Energy tariffs	Sign up to time-based tariff	One-off	User	Moderate	Moderate to High	None	-
	Optimise consumption for time-of-use tariff	Habitual	User	Low to Moderate	Moderate	Possible savings	Moderate
	Optimise consumption for dynamic tariff	Habitual	User	Low to Moderate	High	Possible savings	High
Demand flexibility programmes	Sign-up for voluntary demand reduction events	One-off	User	Low	Moderate	None	-
	Participate in voluntary demand reduction events	Recurrent	User	Moderate	Low	Possible savings	Low to Moderate
	Enrol in direct load control programme	Recurrent	Utility	Low	Moderate	None/possible savings	Moderate to High

Table 3: Uptake and flexible use of demand flexibility enabling technologies

Sub-category	Behaviour	Frequency	Primary agent	Behavioural Effort	Cognitive Effort	Financial Cost	Energetic Impact
Adoption	Install a smart meter and in-home display	One-off	User	Low to Moderate	Low to Moderate	Low	Low
	Adopt smart appliances	One-off	User	Moderate	Moderate	Low to Moderate	Low to Moderate
	Adopt a heat pump	One-off	User	High	High	High	-[2]
	Adopt an EV with a home charger	One-off	User	Moderate	High	High	-
	Install solar PV	One-off	User	Moderate	High	High	High
	Install home battery storage	One-off	User	Moderate	Moderate	Moderate to High	High
Flexible use	Monitor energy consumption patterns and cost using in-home displays	Habitual	User	Moderate	Moderate	None	Low
	Integrate appliances with smart energy management systems	One-off	Appliance	Low	Moderate	Possible savings	Moderate
	Schedule activities like laundry, dishwashing, or water heating to align with time-based tariffs or grid emissions	Recurrent at irregular interval	Appliance	Moderate	High	Possible savings	Moderate
	Run heat pumps off-peak or at times of clean energy abundance/low prices	One-off	Appliance	Low	Moderate	Possible savings	High
	Use smart chargers to align with time-based or grid emissions	One-off	Appliance	Low	Moderate	Possible savings	High
	Use solar generated energy flexibly	Habitual	User	Low to Moderate	Moderate to High	Possible savings	High

[2] The adoption of technologies such as heat pumps and EVs in itself greatly increases the electricity demand of a household.

2.5. Target demand flexibility behaviours

The taxonomy outlined in the Technical Appendix and summarised above can help identify behaviours that are likely to be more effective to target. These are primarily appliance-led behaviours that require less behavioural or cognitive effort and have a low financial cost, making them more likely to be adopted by energy users and result in a substantial energy impact on the grid:

- **Programme appliances to run off-peak:** Schedule the use of electrical appliances or integrate smart appliances with time-based tariffs to run during off-peak hours or times of electricity abundance. Some of the most energy-intensive activities are laundry, water heating, and dishwashing. These can be optimised through the use of time-programming on washing machines, dishwashers, and immersion water heaters. Automation and remote-control-enabled by smart appliances can be a strong aid.
    - Optimising use for a time-based tariff may result in a higher likelihood of the above actions. However, real-world findings on such tariff effects are mixed. Incentives and peak to off-peak ratios need to be large. Dynamic tariffs have larger potential energetic impact and associated savings but require significant efforts in the absence of costly technology.
- **Use solar-generated energy flexibly:** Align onsite consumption with solar PV generation, integrate the system with a home battery if possible, to store for use when most is needed, and sell any excess at optimal (high-demand) periods.
- **Charge EV during off-peak or times of clean energy abundance:** Integrate EV chargers with time-based tariffs or manually set specific charging schedules based on off-peak hours or times of electricity abundance. EV specific tariffs with strong incentives are available, and for many people with an EV, scheduling the charging to occur at the right time should be relatively straightforward.
- **Run heat pumps during off-peak or times of ample clean energy:** Integrate heat pumps with time-based tariffs or manually set specific running schedules based on off-peak hours or times of electricity abundance.

These are (at least in many cases) one-off behaviours that can be technically complex, as they require changing settings and integration with tariffs and devices. Therefore, promising behavioural strategies are those that raise awareness and inform energy users about the possibility of using appliances in a flexible way. Additional interventions should provide instructions and advice, and simplify processes to make reconfiguring and integrating technologies as accessible and user-friendly as possible. These interventions will increase users' capability to perform these behaviours. Furthermore, social recognition and comparisons with others performing these behaviours can encourage action, especially as these are relatively new and may be perceived as uncertain or risky.

While the behaviours above offer the greatest potential for flexibility in terms of shifting electricity consumption to off-peak times or periods of energy abundance, it’s important to note that, for most, the required technologies may be costly to install in the first place and lead to increased overall household electricity consumption. This means that these target behaviours are likely more suited to users who already own these technologies (that is, smart appliances, solar PV and home battery storage, and EVs and chargers) or who have the financial means to do so. For users who do not currently own the aforementioned enabling technologies, the most effective behaviours to target are those that are easily adopted due to their low financial cost and minimal effort required:

- **Water heating:** Avoid using electricity to heat water at peak times. Smart controls make this easier but are not necessary. Avoiding showering at home during the evening peak is also impactful.
- **Laundry:** Avoid tumble dryer use by air drying clothes; less time-intensive behaviours are opting for colder washes and shifting laundry activity away from weekday peak periods.
- **Cooking:** Minimise the use of traditional ovens and opt for more energy-efficient alternatives like air fryers. Prepare meals in advance by batch-cooking at weekends. Cooking is the most common evening peak-period residential activity (Lavin & Julienne, 2025). Despite having relatively less flexibility than activities such as dishwashing and laundry (that is, a smaller proportion of cooking activity can be shifted), its prevalence and energy-intensity means it has the greatest absolute flexibility potential in residential settings.

These behaviours are typically habitual or recurrent, requiring frequent engagement from energy users. They are also more straightforward than the previously mentioned behaviours. Therefore, encouraging these behaviours may require different strategies, such as prompting users to plan and set goals that can help establish habits. Additionally, providing timely reminders, environmental cues, and salient signage can prompt action and support habit formation. This is because habitual behaviours are often context dependent and performed automatically; salient cues can trigger these automatic responses. These cues can include notifications, visual highlighting of relevant appliance settings (for example, cold wash settings on washing machines), or adjusted default settings on smart thermostats.

3. Electricity demand flexibility roadmaps

3.1. Introduction

Mapping demand flexibility activities is helpful for understanding the steps energy users take to engage with technologies, tariffs, or programmes that enable them to shift or reduce their energy usage. The purpose of these roadmaps is to visualise and analyse the pathways energy users navigate as they adopt behaviours and technologies that contribute to a more flexible, sustainable energy system (see SEAI, 2020a; 2020b, and 2023b for applications of this approach to EV, heat pump, and retrofitting uptake, respectively). By identifying key stages, behaviours, barriers, and enabling factors, it highlights opportunities to design interventions that accelerate engagement and maximise participation in demand flexibility initiatives.

The journey towards achieving demand flexibility can be understood as a combination of various behaviours and technologies, at the end of which individuals or businesses become not only energy-conscious and proactive energy users but, ideally, flexible prosumers. However, this overarching journey is composed of many smaller, individual journeys tied to specific technologies, tariffs, programmes, or behaviour changes. For instance, demand flexibility behaviours may involve switching to a time-based tariff, enrolling in automated demand side flexibility programmes, or adopting energy storage solutions. While the ideal energy user seamlessly integrates these activities, each component involves unique challenges and behaviours that must be understood and addressed. Dissecting the journey towards achieving demand flexibility into the adoption and flexible use of certain technologies; the sign-up to tariffs or programmes; and the habit changes needed, allows us to acknowledge that "achieving demand flexibility" has a different meaning for different population segments as a result of their financial capabilities, while not forgetting the co-dependencies of different behaviour and technologies on one another.

A critical starting point for most demand flexibility journeys is the presence of enabling technologies, particularly smart meters that measure real-time energy usage and in-home displays or mobile apps that provide consumers with actionable insights. These tools allow individuals to better understand their energy consumption patterns and, in turn, make informed decisions to adjust usage. In Ireland, smart meter roll-out has reached significant levels under the National Smart Metering Programme, delivered by ESBN and overseen by the CRU with support from the Department of the Environment, Climate and Communications, SEAI, and energy providers. Approximately 1.9 million smart meters have been installed to date. The rollout is on track to achieve full coverage of approximately 2.1 million customers by the end of 2025. Given the widespread adoption of smart meters in Ireland, this report does not include a detailed mapping of the journey towards smart meter uptake. Instead, it focuses on the subsequent stages of demand flexibility engagement.

Each roadmap follows stages adopted from the Transtheoretical Model of Behaviour Change (Prochaska and Velicer, 1997), reflecting the progression energy users make from lack of awareness to sustained behaviour change. Furthermore, each roadmap also considers:

- **Who can start the journey:** Technical, financial, and structural prerequisites play a critical role in determining whether someone can start a particular journey. For example, while smart meters are necessary for time-based tariffs, heat pump adoption may require home insulation upgrades or access to grants and financing schemes.
- **Who is likely to start the journey:** Certain demographics may be better positioned to engage in certain technologies or behaviours related to demand flexibility. For example, those with better financial situations, flexible work arrangements, or fewer household responsibilities.
- **When they are likely to start:** Energy users are often prompted to begin a particular journey by internal or external triggers. For example, internal triggers can include recognising high energy bills or seeking comfort and sustainability benefits, while external triggers may include government incentives, the adoption of another technology/habit or significant life events.

By including these considerations, we highlight the critical co-dependencies between technologies and behaviours. For instance, adopting time-based tariffs depends on having a smart meter, while effective use of heat pumps may require behavioural adjustments to optimise energy efficiency. At the same time, the roadmaps acknowledge the limitations and barriers energy users face, such as financial constraints, perceived complexity, or lack of support and clear guidance. To address these barriers, each roadmap includes a set of actionable policy recommendations or solutions broken down by stage to help energy users move forward on their journey.

Generally, these solutions are geared towards making engagement with demand flexibility in various ways easier, social where possible, attractive in that they appeal to the strongest motivations, and timely, for example, by cueing people to a given action at an opportune or appropriate moment rather than requiring them to remember or hold information for a period of time (Behavioural Insights Team, 2014). To make change, people need support in terms of providing suitably enabling environments, and provision of opportunities to act (Michie, 2011). The likelihood of behaviour change is highest when capability, opportunity, and motivation are all targeted by a given intervention. However, enhancing any of them is still worthwhile, as each of these facets tend to affect the others.

In the following sections, we present detailed roadmaps for key demand flexibility activities identified in the previous section, namely 1) Behavioural changes (consumption shaving and shifting), 2) Engagement with demand flexibility programmes and services (electricity tariff switching and demand response programme participation), and 3) Uptake and flexible use of demand flexibility enabling technologies (smart appliances, heat pumps, EVs and solar PV).

3.2. Behavioural changes

3.2.1. Peak shaving and shifting behaviours roadmap

Peak shaving and peak shifting are complementary strategies aimed at reducing energy consumption during high-demand periods and redistributing energy use to off-peak hours, or times that align with abundant renewable energy. These behaviours not only alleviate stress on the electricity grid but also contribute to grid stability, enhance the integration of renewable energy sources, and reduce energy costs for energy users. Both approaches are relevant to households and businesses alike, with no prerequisite for smart meters, though their impact is more visible for those with energy-intensive appliances.

Peak shaving focuses on reducing energy consumption during peak demand periods, typically early evening, to alleviate pressure on the grid. It involves a combination of one-off adjustments and habitual behaviours. One-off actions, such as installing energy-efficient appliances or reprogramming systems to avoid or minimise energy use during peak times, require upfront planning and investment but can have lasting effects. On the other hand, habitual changes include ongoing, repeated actions like turning off lights in unused rooms, slightly lowering thermostats during the winter, or consistently adjusting usage patterns during peak hours. These behaviours require attention, discipline, and gradual incorporation into daily routines. These behaviours can be prompted by both incentivised demand side flexibility programmes and non-incentivised tools like reminders or visual cues from apps that reflect current grid conditions.

Peak shifting, in contrast, focuses on redistributing energy use to off-peak hours when demand is lower, energy is cheaper, and generation is often more sustainable. By rescheduling energy-intensive activities, such as running washing machines, dishwashers, or water heaters, to low-demand periods, energy users can reduce their energy costs and support a more sustainable grid. Peak shifting behaviours similarly include one-off actions, like setting up timers or using smart appliances remotely to automate tasks, as well as habitual changes, such as preparing meals in advance or adjusting household routines to align with off-peak hours.

Although peak shifting is more accessible and immediately actionable for most households, both approaches demand sustained efforts to establish long-term routines. For maximum flexibility, these strategies must combine short-term interventions—like reprogramming or automating appliances—with sustained efforts to build energy-saving behaviours into daily life. Importantly, ongoing engagement, reinforcement, and feedback from energy providers play a crucial role in maintaining momentum.

Starting requirements

Any energy user can embark on the journey to consumption shaving and shifting; there are no significant prerequisites. However, energy users on time-based tariffs or enrolled in demand side flexibility programmes often benefit from financial incentives that make these practices more rewarding, especially when habits haven't been consolidated yet. Additionally, energy users equipped with (remotely) programmable smart devices, such as smart thermostats or appliances, can more easily automate and optimise their energy use, simplifying the process of having to manually adjust consumption patterns.

Energy users most likely to start the journey to peak shaving and peak shifting are those with a good understanding of their energy usage, often facilitated by tools such as in-home displays or energy monitoring apps. Additionally, households with flexible schedules such as retirees, or those without dependents may find it easier to adjust routines and reschedule energy-intensive activities to times of energy abundance. Finally, households with strong pro-environmental values are often drawn to these behaviours as a way to reduce their carbon footprint.

PEAK SHAVING & SHIFTING | ROADMAP TO FLEXIBILITY

	TRIGGER	Stage 1 **CONSIDERATION & PLANNING**	Stage 2 **ACTION**	Stage 3 **SUSTAINING FLEXIBLE BEHAVIOUR**
BEHAVIOURS	Any energy user can start the journey. Users are prompted to start by information campaigns or promotions, by having a smart meter installed or by an increase in electricity bills (e.g. after adopting a high-consumption appliance).	Energy users review their bills to understand their use and pin-point what activities they can reduce or shift to off-peak times, making use of tools like apps or in-home displays if available. They also research automation tools and explore how to operate existing smart appliances more effectively.	Users start changing their consumption at peak times, including by reducing their use of non-essential appliances (e.g. air-drying clothes rather than using the dryer), using more efficient appliances (e.g. using an air fryer rather than the oven) and shifting their use of large appliances to off-peak times (e.g. using timers to run laundry overnight).	Users incorporate changes into daily routines and refine settings on smart appliances and automation tools to optimise the balance between reducing peak consumption and convenience, while also responding to seasonal changes.
BARRIERS	Lack of awareness & status quo bias Scepticism about impact of individual actions & perceived lack of fairness	Poor understanding of appliance consumption Confusion & information overload Lack of access to enabling tools (e.g. in-home displays)	Lack of immediate feedback or rewards Pushback from other household members Time constraints & competing priorities	Difficulty maintaining motivation Lack of visible savings Change in household circumstances or routines
SOLUTIONS	▶ Educate users about the need for demand flexibility and the multiple benefits of reducing peak demand ▶ Ensure that flexibility policies and measures directed at large energy users are communicated to the public	▶ Help users understand which appliances use the most electricity through real-time feedback ▶ Target behaviours that are easy to shift ▶ Highlight collective benefits	▶ Make feedback & financial rewards more immediate ▶ Promote community peak challenges	▶ Foster emotions of pride by highlighting households' contributions to reducing emissions ▶ Support the integration of automation technologies ▶ Incorporate gamification to in-home displays and apps ▶ Improve financial incentives for peak shifting

Trigger

Information campaigns and energy provider promotions of flexibility products are likely triggers for many. The installation of smart meters with in-home displays or apps that increase awareness of energy consumption can also play a role. Users might also be motivated to explore energy saving options due to increased electricity bills resulting from rising energy costs, seasonal changes or the adoption of high-energy-consumption appliances, such as EVs or heat pumps. Additional triggers include energy audits that identify peak shaving as a cost-saving opportunity.

Barriers

A lack of understanding about current energy usage, status quo bias, and a simple lack of awareness of the issue can prevent change. Scepticism about the impact of individual actions and potential savings can further hinder engagement. A related barrier is a perceived lack of fairness in being asked to make changes when large energy users (for example, data centres), are disproportionately responsible for energy consumption. Most people are conditional co-operators in collective action problems, such as the climate crisis, meaning that will do what they perceive to be their fair share so long as they believe other actors are doing so too (Keser and van Winden, 2000; Becchetti et al., 2025).

Potential solutions

- **Educate energy users about the need for demand flexibility and the multiple benefits of reducing peak demand**. Providing targeted information about the high costs and environmental impacts associated with peak energy consumption can drive shifts in behaviour (Mansor and Low, 2019). Users are drawn to smart energy by the potential to monitor use and control bills, but it is also essential to communicate grid and environmental benefits as awareness of these is associated with significantly greater behavioural intentions (SEAI, 2025).
- **Ensure that flexibility policies and measures directed at large energy users are communicated to the public.** This is likely to increase perceptions of fairness, which are particularly important in household flexibility intentions.

Stage 1: Consideration and planning

In the consideration and planning stage, energy users may review their energy bills to understand their usage. Analysing energy data from apps, in-home displays, or bills helps pinpoint which activities, such as laundry, EV charging, or heating, can be reduced or shifted to off-peak hours. During this stage, energy users may also research automation tools, such as smart plugs, timers, or apps, and explore how to operate smart appliances effectively.

Barriers

Generally, lay intuitions about the energy intensity of different activities are poor (Lesic et al., 2018), and the majority of people are unfamiliar with units of energy consumption. Thus, difficulty identifying high-energy activities and understanding effective actions can slow progress. Uncertainty about the actual cost or energy savings achieved by these actions adds to hesitation–users may be sceptical about the impact of individual actions. Energy users may struggle with information overload or confusion due to unclear communication from energy providers, as well as a lack access to enabling tools like apps or in-home displays.

Potential solutions

- **Help energy users understand which appliances use the most electricity** by developing user-friendly in-home displays and apps with **real-time feedback** to help people visualise savings and build a better understanding of the key activities to change (Buchanan et al., 2014).
- **Target behaviours that are easy to shift.** Make sure awareness campaigns that encourage shifting consumption to off-peak times focus on more flexible behaviours such as use of washing machines, dishwashers, and electric vehicle charging. (Expert interview)
- **Highlight collective benefits of energy conservation at peak times.** This can encourage individuals to reduce their consumption during critical periods, especially environmentally conscious energy users (EPA, 2024).

Stage 2: Action

During the action phase, energy users begin implementing changes to their consumption. They reduce non-essential device usage (for example, by air drying clothes rather than using a tumble dryer) during peak times and optimise water and heating efficiency, such as by installing low-flow showerheads or lowering thermostat settings. In the kitchen, they adopt efficient cooking methods, such as batch cooking or using energy-efficient appliances like microwaves or air fryers. They also improve lighting efficiency by installing LEDs and turning off unused lights, unplugging standby devices, and scheduling washing machines and dishwashers overnight or during periods of energy abundance.

Barriers

Lack of immediate feedback or rewards (for example, from energy providers) can demotivate households, as savings may not be immediately apparent. Discomfort or inconvenience from adopting new behaviours, pushback from other household members, and technical issues with devices or automation tools also present challenges. Time constraints and competing priorities, combined with resistance to changing routines, create further difficulties.

Potential solutions

- **Make feedback and financial rewards more immediate** (for example, visible on the next energy bill), enhancing customer engagement by providing real-time feedback (Expert interview). Energy providers can consider providing free kWh credits to customers who opt into peak demand reduction programmes, ensuring immediate financial benefits.
- **Promote community peak challenges** such as local "Energy Smart Neighbourhoods" whereby communities compete to collectively reduce peak-time usage, with rewards such as bill credits or community grants, capitalising on people's tendency to compare themselves to others and follow social norms. This approach can create collective motivation and a shared identity, thereby supporting overall reductions in peak demand (Guasselli et al., 2024).

Stage 3: Sustaining flexible behaviour

In this final stage, energy users incorporate shaving and shifting behaviours into daily routines. This may take time and involve some experimentation and refinement of their schedules, to balance convenience with energy savings while also responding to seasonal changes. They also refine settings on smart appliances and automation tools to maximise savings, and some energy users even explore complementary technologies, such as battery storage or solar panels, to enhance energy management capabilities.

Barriers

Despite initial efforts, households may encounter challenges maintaining motivation. A lack of ongoing feedback or visible savings can lead to habit fatigue or a decline in effort over time, especially if household circumstances change and disrupt routines. Limited engagement from other household members and scepticism about the effectiveness of the energy-saving efforts can further decrease collective engagement.

Potential solutions

- **Foster emotions of pride by highlighting households' contributions to reducing emissions**, such as by implementing "Your Energy Impact" reports for households, or featuring real-life testimonials of individuals or businesses making a difference. Positive emotional reinforcement can motivate individuals to reduce their energy use (Carrus et al., 2021).
- **Support the integration of automation technologies,** such as smart devices for managing appliance schedules. Automating the time-shifting of energy-intensive activities can reduce consumer burden and encourage flexible consumption practices (Piano and Smith, 2022).
- **Incorporate gamification to in-home displays and apps**. Include elements such as goals, weekly energy saving challenges, and a sense of progression to motivate households to engage in time-shifting behaviours. Making these symbolic incentives achievable and visibly showing progress can make energy-saving efforts more engaging and rewarding (Morganti et al., 2017).
- **Improve financial incentives for peak shifting** by sculpting tariffs that make peak and off-peak rates more financially distinct (Faruqui and Sergici, 2013).

Future directions

Based on the conducted review and expert interviews, we identified the following outstanding research questions:

- How do the size and structure of financial rewards (for example, when combined with participation in a demand side flexibility scheme or time-based tariff adoption) influence household engagement in peak shifting and shaving behaviours?
- Who are the most persuasive messengers to encourage engagement in peak shaving and shifting behaviours? For example, is the encouragement most effective when it comes from heads of households, building managers, or local community leaders?
- How do we combine different types of incentives to ensure sustained habit change? For instance, could novelty and gamification drive initial engagement, with a gradual shift to financial or symbolic rewards as the novelty effect wears off?

3.3. Demand flexibility programmes and services

3.3.1. Electricity tariff switching roadmap

Conventional tariffs charge the same price for electricity at all times of day. Time-based tariffs have different rates at different times of the day or of the week to reduce energy usage during peak periods by incentivising energy usage during off-peak hours when demand on the grid is lower. There are several different versions, under two broad classes. Time-of-use (ToU) tariffs have rates for different set windows throughout the day. Prices are generally highest between 4 and 7 pm to discourage evening peak consumption. For residential customers, ToU tariffs often come in two-period (Day-Night) or three-period (Day-Night-Peak) structures. Dynamic tariffs go a step further by reflecting real-time changes in electricity supply and demand, often through hourly or half-hourly pricing linked to wholesale electricity prices. Such tariffs can bring significant savings, particularly for those with flexible work schedules or without dependents in the household, as they can more easily adapt their consumption patterns to take advantage of variable pricing.

In Ireland, ToU tariffs were introduced in 2021 as part of the Smart Metering Programme and require smart meters as a prerequisite. Each electricity provider is mandated to offer a Standard Smart Tariff, which incorporates a peak-period rate. To support energy user understanding and engagement, the Commission for Regulation of Utilities (CRU) introduced "Time-of-Use Primers," informational guides explaining how time-based tariffs work and their benefits (Barjaková et al., 2024). In 2023, ESBN proposed a revision to the content and timing of the primers, as well as a proposal to extend the requirement for energy providers to send these primers beyond 2025 (ESBN, 2023b).

Large suppliers (those with 200,000 customers) are required to offer dynamic tariffs by the 1 June 2026. Some suppliers offer free weekend electricity with higher rates during the week; and EV-specific rates, with very low prices between 2 and 5 am, are also available.

Starting requirements

To start the journey towards enrolling in time-based tariffs, households require a smart meter that tracks electricity consumption on a sufficiently granular level. Energy users who are already monitoring their energy usage (for example, via an in-home display or app) and hold stronger pro-environmental values are more likely to enrol in dynamic or ToU tariffs. Additionally, households with the flexibility to adjust their energy use—such as those with flexible work schedules or without dependents (that is, young children or elderly)—are more likely to adopt these tariffs, as they can more easily adapt their consumption patterns to take advantage of variable pricing.

Triggers

Smart meter installation often serves as a trigger, providing the technology necessary to monitor energy usage and take advantage of these plans. The adoption of high-energy-consuming appliances like EVs or heat pumps also increases the relevance of time-based tariffs. Other common triggers include increased energy costs or a “bill shock,” recommendations from friends or family, and energy provider notifications regarding tariff renewals or new products.

Barriers

However, several barriers can lessen the effect of these triggers. Perceived complexity and information overload often deter households from engaging, and a perception that time-based tariffs are not personally relevant can also impede action. Furthermore, households without high energy load devices may view the cost-saving benefits as insufficiently compelling. More fundamentally, many are unaware that once they have a smart meter installed, they still need to switch tariff to take advantage of lower off-peak prices (SEAI, 2023a).

ELECTRICITY TARIFF SWITCHING | ROADMAP TO FLEXIBILITY

TRIGGER

BEHAVIOURS

An energy user must have a smart meter installed to start.

Users are usually prompted by smart meter installation. Other triggers include adoption of a high-consumption appliance (e.g. EV, heat pump), a bill shock, a recommendation from friends or family and utility notifications around contract renewal or new products.

BARRIERS

- Lack of awareness of the need to switch tariff to avail of off-peak rates
- Perceived complexity & information overload
- Lack of perceived relevance & insufficient cost savings

SOLUTIONS

- Provide simple, consistent communication about how time-based tariffs work
- Standardise tariff naming & terminology
- Pilot different communication frames

Stage 1 CONSIDERATION & PLANNING

BEHAVIOURS

Energy users assess which tariffs best align with their energy usage habits. They get information and advice online, from utility customer services teams, price comparison websites, or from their peers. Some users may use consumption data from their smart meter to help them estimate how much they could save by switching.

BARRIERS

- Lack of data literacy & difficulty assessing fit
- Lack of data integration with price comparison websites
- Complexity aversion

SOLUTIONS

- Introduce an education process for customers before they enrol in time-based tariffs
- Promote the development of standardised consumer tools that are easily integrated with smart meter data
- Highlight both the financial and environmental benefits of time-based tariffs

Stage 2 ACTION

BEHAVIOURS

Energy users select the tariff that best suits their needs and make the switch. This involves gathering information and filling out the necessary forms. They also need to inform other household members of the change, and the behavioural adjustments needed, and may set up monitoring tools such as a mobile app.

BARRIERS

- Difficulty gaining buy-in from other household members
- Concerns about lifestyle adjustments
- Loss aversion & fear of higher bills

SOLUTIONS

- Provide simple time-based pricing structures for energy users without past experience
- Reduce risk of switching using trial periods or price guarantees

Stage 3 SUSTAINING FLEXIBLE BEHAVIOUR

BEHAVIOURS

After switching, users refine their electricity consumption habits to maximise the savings they make on their new tariff.* They might use monitoring tools to help track their usage and respond to notifications and feedback from their provider.

**see peak shaving and shifting roadmap*

BARRIERS

- Difficulty assessing savings due to price fluctuations
- Difficulty sustaining motivation & habits

SOLUTIONS

- Support the adoption of automation technologies
- Display the savings achieved from switching to a time-based tariff on bills

Potential solutions

- **Provide simple, consistent communication about how time-based tariffs work**. This should include plain-language descriptions, decision trees, simple tables listing peak and off-peak prices, FAQs, and visuals to aid comprehension (Barjaková et al., 2024; Belton and Lunn, 2020).
- **Standardise tariff naming and terminology.** Various terms are used by different suppliers and entities to describe time-based tariffs. More consistent naming across all energy providers and public service bodies would reduce the likelihood of consumer confusion and improve adoption.
- **Pilot different communication frames**, such as communications emphasising cost-savings vs. grid stability vs. community benefits. This will ensure that the information provided resonates with energy users in the best way possible (SEAI, 2025b).

Stage 1: Consideration and planning

Households evaluate whether time-based tariffs align with their current energy usage habits or if they could make changes to these habits in order to benefit. They seek additional information by visiting energy provider websites, researching online, or consulting peers. Some households then analyse their current energy usage patterns using past bills, smart meter data, or online energy reports to estimate potential savings. At this stage, energy provider customer service teams can play an important role in helping customers understand their consumption and address any questions or concerns about new tariffs.

Barriers

In Ireland, access to detailed energy usage data has improved with the rollout of ESBN's My Smart Data portal, which allows energy users to download their smart meter data. However, significant barriers remain—using the portal requires a level of data literacy that many energy users may not possess, limiting its effectiveness. Until recently, price comparison websites lacked the functionality to integrate smart meter data directly; one Irish site now provides this feature. However, difficulty in assessing whether time-based tariffs are a good personal fit is still a significant barrier, particularly for those without high data literacy, and it is often compounded by a lack of available detailed data on current energy usage. Worth pointing out here too is that the supposed function of time-based tariffs is to shift consumption away from peak periods. Thus, users ideally need to assess whether the tariff could be a good fit for alternative future consumption pattern. Inertia, complexity aversion and loss aversion contribute to reluctance to adopt tariffs that introduce variability (Nicolson et al., 2017).

Potential solutions

- **Introduce an education process for customers before they enrol in time-based tariffs** to ensure they understand the risks and benefits (Expert interview).
- **Promote the development of standardised consumer tools that are easily integrated with smart meter data (**for example, tariff comparison websites) to help customers make informed choices about different time-based tariffs, reducing complexity and information overload (Belton and Lunn, 2020).
- **Highlight both the financial and environmental benefits of time-based tariffs**. Emphasising their contribution to energy system decarbonisation and the direct cost benefits of load shifting can enhance participation, especially among environmentally conscious users (Hansen and Aagaard, 2024; SEAI, 2025b).

Stage 2: Action

Once a decision is made, energy users move on to selecting the tariff that best suits their needs—whether it's a simple peak/off-peak structure or a more complex seasonal tariff—and actually making the switch. This involves gathering the necessary information, such as account details and energy usage data, to complete the enrolment process by filling out online or phone forms and agreeing to terms and conditions. Next, they might set up access to monitoring tools, such as mobile apps, to track their energy usage. During this stage, the person in charge of the decision may also inform other household members of the change and discuss the behavioural adjustments needed to maximise savings.

Barriers

Difficulty in gaining buy-in from other household members may arise where users feel that changing tariffs reduces their control over energy costs and usage. Concerns about lifestyle adjustments needed for the new tariff to bring savings, coupled with loss aversion and fear of higher bills if they fail to shift their behaviour, further hinder switching.

Potential solutions

- **Provide simple time-based pricing structures for energy users without past experience** of time-based tariffs. These simple tariffs should have limited and easily-comprehensible peak and off-peak blocks. Reducing the complexity of time-based tariffs to predictable time slots can facilitate greater engagement from energy users, who might otherwise find complex pricing signals daunting (Kessels et al., 2016; Belton and Lunn, 2020).
- **Reduce risk of switching using trial periods or price guarantees.** Implement "safety nets" or price guarantees for initial contract periods in which the maximum that customers pay is equal to what they would have paid according to their old rate structure; and implement an option to revert to a flat structure at any time.

Stage 3: Sustaining flexible behaviour

After switching, energy users refine their new energy usage habits to maximise their gains with the new tariff. Essentially, this stage entails the steps of the previous roadmap on peak shifting and shaving. It often involves tracking energy consumption, and manually shifting the use of appliances (such as washing machines and dishwashers) as well as high-consumption activities (for example, charging of EVs) to off-peak hours. Energy users also respond to notifications and feedback from their provider, adjusting their energy habits as needed. Over time, they are able to evaluate their savings by comparing bills before and after the switch.

Barriers

Evaluating savings by comparing bills can be complicated by changes to energy prices over time. And despite initial motivation, sustaining new habits can be difficult, especially if monitoring tools are insufficient or provide overwhelming data. Bill confusion and unexpected costs can quickly diminish trust and motivation. For some, perceived savings may not justify the effort, while limited control over peak usage due to household circumstances (for example, family schedules) may make achieving flexibility challenging.

Potential solutions

- **Support the adoption of automation technologies**, such as smart appliances, for households enrolled in time-based tariffs. For example, energy providers can provide information to customers who recently switched to a time-based tariff about how automation devices operate, their benefits, where to purchase such devices, and how to optimise the devices to work together with time-based tariffs. Policies should promote smart devices that automatically adjust energy usage according to price signals, thereby reducing the energy user's need to interact with complex pricing structures (Kessels et al., 2016).
- **Display the savings achieved from switching to a time-based tariff on bills,** so that customers can assess savings easily without needing to do their own calculations.

Future directions

From the literature review and stakeholder insights, the following key areas are proposed for further research to optimise the design and adoption of time-based tariffs:

- What is the optimal balance between peak and off-peak periods, in terms of durations and pricing differentials, to maximise participation without deterring users? Are there contexts where complex tariffs (for example, 3-band, dynamic pricing) would deliver greater flexibility while being well received by energy users?
- To what extent and for whom can various "safety nets" such as price guarantees and try-before-you-buy schemes drive additional tariff uptake?

- To what extent can low-income households benefit from time-based tariffs, given their already low energy consumption? How can these programs be tailored to be equitable?
- To what extent can environmentally conscious users or other demographics be effectively motivated through non-financial incentives?
- What external triggers (for example, rising energy costs policy mandates) are most effective in overcoming inertia and promoting tariff switching?

3.3.2. Demand response programme participation roadmap

Demand side flexibility programmes play a critical role in balancing electricity supply and demand and improving grid stability, especially in the occurrence of extreme events. These programmes offer participants—ranging from large energy users to individual households—opportunities to reduce energy consumption during critical periods. Generally, this takes one of two forms. The first involves users turning appliances off or settings down in response to notifications or alerts the energy provider, which we will call voluntary response programmes. The second is termed direct load control in which energy-users sign up to allow energy providers to control some appliances (for example, water heater immersions, heat pumps, freezers) remotely (usually with an option to override) in exchange for financial reward. Direct load control contracts are not currently available to Irish energy users but could be an important future mechanism. ESBN has been piloting a similar initiative, Conservation Voltage Reduction (CVR). CVR reduces system voltage to the low end of standard range to reduce overall demand while maintaining levels that are acceptable to end-users (ESBN, 2024).

Regardless of whether actions are directly controlled by end-users or remotely controlled by energy providers, the adjustments are usually incentivised through financial rewards. They can also, however, be driven by information alone, in which case energy users are expected to make informed decisions without direct compensation.

More prominently, ESBN piloted a voluntary response programme, *Beat the Peak,* in October 2022 to help all energy users, regardless of their energy provider, to take control of their home's electricity usage by providing them with relevant and timely information and rewards for reducing demand in response to prompts. Over 18,000 energy users signed up and self-reported more than 40,000 actions to help support Ireland's security of supply and reduce reliance on fossil fuels. The scheme continues to run under the *Is This a Good Time?* campaign.

In programmes such as this, participants maintain full control over their energy use, with options to reduce non-essential energy consumption or use backup energy sources like battery storage or onsite generation. For energy providers to assess whether energy users responded to these events and to provide appropriate incentives, access to accurate consumption data is essential. Currently, many programmes (including those run by ESBN) rely on self-reported data, which limits the ability to measure and reward participation effectively.

As demand side flexibility evolves, the reliance on financial incentives may decrease, with behavioural norms shifting towards routine responses to grid signals. In the future, users might adjust their energy use out of habit or environmental awareness, responding to simple app notifications or visual cues without expecting compensation. As such, this framing of demand side flexibility—encompassing both incentivised and non-incentivised measures—ensures the adaptability of these programmes to changing energy landscapes.

The process of enrolling in a demand side flexibility programme follows a similar preparation process to switching to a new tariff, with the roadmap consisting of three stages: consideration and planning, action (in this case enrolling in the programme), and sustaining the behaviour. However, unlike shifting energy consumption to off-peak times, the behaviour in the final stage differs significantly, as demand response events occur at irregular intervals.

Starting requirements

Households generally need a smart meter and good internet connectivity to enable real-time energy monitoring and communication with their energy provider. Households that are likely to start the journey towards participating in demand side flexibility programmes include those motivated by environmental concerns and with higher levels of awareness about energy consumption, desire for energy efficiency, and a more proactive approach to energy management.

DEMAND RESPONSE PROGRAMME PARTICIPATION | ROADMAP TO FLEXIBILITY

TRIGGER

BEHAVIOURS

Any energy user can start the journey.

Users are first prompted by recommendations from friends or family, utility notifications or ad campaigns.

BARRIERS

- Misunderstanding programme purpose

SOLUTIONS

- ▶ Raise awareness of the financial and environmental benefits of participating in demand-side flexibility programmes

Stage 1 CONSIDERATION & PLANNING

BEHAVIOURS

Energy users seek further information and evaluate whether participation aligns with their usage patterns and lifestyle.

More in-depth consideration is required for direct load control contracts. Users research the potential for service disruption and their ability to override direct control, weighing the risks against the benefits.

BARRIERS

- Status quo bias
- Privacy concerns
- Reluctance to cede control

SOLUTIONS

- ▶ Address concerns about privacy & trust (e.g. data security assurances)
- ▶ Address concerns about loss of control (e.g. emphasise ease of override)
- ▶ Offer smart home appliances that have been pre-enrolled to direct load control

Stage 2 ACTION

BEHAVIOURS

Enrolment involves signing up and sharing required information. Users must also set preferences and agree to the programme's terms and conditions.

Direct load control often requires the installation of new smart technologies.

BARRIERS

- Complicated enrolment procedures
- Worry about service disruption
- Lack of buy-in from other household members

SOLUTIONS

- ▶ Provide meaningful financial incentives and market frameworks for energy users to participate in demand-side flexibility programmes

Stage 3 SUSTAINING FLEXIBLE BEHAVIOUR

BEHAVIOURS

Energy users continue to respond to requests to voluntarily reduce their demand.

In the case of direct load control, they do not override their utility's operation of appliance to curtail consumption.

BARRIERS

- Limited visibility of savings & rewards
- Declining motivation
- Lack of verification of actions using meter data

SOLUTIONS

- ▶ Help energy users understand how they can shift their energy use
- ▶ Implement mechanisms to verify real actions taken by customers during demand response requests

Trigger

Triggers for participating in a demand response programme are likely to take the form of external influences such as recommendations from friends and family, energy provider notifications about benefits, along with ads, news or campaigns offering financial rewards.

Barriers

Barriers include a view of enrolment as inconvenient, compounded by misunderstandings about the programme's purpose, or about demand response more generally.

Potential solutions

- **Raise awareness of the financial and environmental benefits of participating in demand side flexibility programmes**. Awareness campaigns should focus on how customers can use these programmes to reduce their electricity bills and contribute to a more stable grid. Highlighting practical benefits such as bill savings and increased reliability can help motivate participation (Ellabban and Abu-Rub, 2016).

Stage 1: Consideration and planning

During the consideration phase, households evaluate whether participating in a demand side flexibility programme aligns with their usage patterns and lifestyle. This stage often involves seeking additional information from energy provider websites, customer service representatives, or online resources. More in-depth consideration is usually required for direct load control participation compared to participation in voluntary demand reduction events programmes.

For the former, users might consult peers or analyse their past energy usage through smart meter data or energy usage reports to assess potential savings or rewards. Users also research the implications of participating, particularly the potential for service interruptions or ability to override direct control. Weighing the risks of inconvenience against the benefits is a critical part of the decision-making process.

Barriers

Barriers include concerns about privacy and the sharing of detailed energy data, especially if energy users do not trust energy companies and perceive them to be prioritising profit over consumer benefits. Many are also reluctant to relinquish control over appliances to energy providers, fearing reduced comfort or health implications.

Relatedly, these programmes entail quite significant changes to the way people interact with energy systems. Status quo bias is a likely deterrent to participation, and indeed to researching programmes in the first instance, particularly in the context of their novelty, and the fact that lay conceptions of the energy system are lacking clarity as it is (Herberz et al., 2020).

Potential solutions

- **Address concerns about privacy and trust**. Providing data security assurances, such as visible data security badges, helps build trust and mitigate data concerns. Consider mandating providers to display real-time information on when and how devices are controlled.
- **Address concerns about loss of control**. This can be done through emphasising the ease of device override, associated financial benefits, and through providing direct load control programmes that are easy to opt out from (Crawley et al., 2021; Siitonen et al., 2023).
- **Offer smart home appliances that have been pre-enrolled to direct load control or demand side flexibility programmes**. Energy providers can offer smart thermostats, heat pumps, and other appliances that have been pre-enrolled in direct load control programmes. The sale of pre-enrolled devices and appliances can be supported by purchase discounts, bill credit bonuses, and easy-to-opt-out direct load control programmes. Selling such pre-enrolled technologies can increase household participation and ease customer involvement in demand response without requiring active daily input (Kowalska-Pyzalska, 2018). An example is the myEnergy Rewards Programme by Canadian utility, Hydro One, which provides discounts on purchasing pre-enrolled smart thermostats (Hydro One, 2024).

Stage 2: Action

The enrolment stage involves signing up (via an online portal, mobile app, or phone call to the energy provider), as part of which participants may provide information about their household energy usage and customise their participation preferences, such as device control settings or usage limits. Next, setting up technologies like smart thermostats or smart plugs is often required to enable load control. Participants also agree to the programme's terms and conditions, which typically include specific hours or conditions for energy adjustments. The decision maker may also inform other household members about potential changes or disruptions, ensuring everyone is prepared for adjustments during demand response events.

Barriers

Despite the procedural nature of this stage, the enrolment process can feel complicated or overly technical, discouraging some participants from completing it. Hidden fees or ambiguous terms can create additional concerns. Households may also worry about service disruptions or find it challenging to gain buy-in from other members. A perceived lack of control during demand response events may also deter participation.

Potential solutions

- **Provide meaningful financial incentives and market frameworks for energy users to participate in demand side flexibility programmes.** The current "token gestures" like small vouchers might not be sufficient to motivate customers (Expert interview).

Stage 3: Sustaining flexible behaviour

Sustained flexible behaviour entails continued response to notifications to voluntarily reduce demand; and in the case of direct load control, not overriding energy provider operations to curtail use of certain appliances. This will sometimes necessitate various forms of effort, for example habit disruption at irregular intervals, reduced comfort, and advanced planning.

Barriers

Limited visibility of savings or rewards may lead participants to question whether the effort is worthwhile. Additionally, reduced comfort or declining motivation over time can hinder long-term engagement. A potential issue in voluntary programmes is that without meter data to verify participation, users can improperly report participation in a given event.

Potential solutions

- **Help energy users understand how they can shift their energy use**. To reduce required behavioural and cognitive effort, provide practical advice on how to shift behaviours outside of peak events (for example, by pre-cooking meals, using a delayed start function on appliances, and going out during a peak event) and help users understand which actions consume the most energy. Using visual aids, clear charts, explainer videos and direct language to communicate how demand response programmes work can help bridge the gap in understanding, particularly for elderly or less tech-savvy participants (Ellabban and Abu-Rub, 2016).
- **Implement mechanisms to verify real actions taken by customers during demand response requests** rather than relying solely on self-reported behaviour (Expert interview).

Future directions

Expert consultations and literature review pointed towards the following research questions:

- To what extent can social motivators such as highlighting collective impact be leveraged to enhance engagement with demand side flexibility programmes?
- What are the broader social welfare consequences of demand side flexibility initiatives? Are there energy user groups for whom these programmes are less beneficial, and how can policies be refined to address this?
- In some instances, interest in demand side flexibility scheme participation declines over time (for example, as the novelty effect wears off). What strategies are effective in maintaining long-term participation?
- How can high-usage consumers who disproportionately affect grid stability be encouraged to participate in demand flexibility schemes?

3.4. Demand flexibility enabling technologies

3.4.1. Smart appliance adoption and flexible use roadmap

Smart appliances, including remotely-controllable washing machines, dishwashers, thermostats, and water heaters, offer households a powerful way to reduce energy consumption and automatically respond to grid-balancing signals via a smartphone app. Features like the ability to connect to the home's Wi-Fi, control and monitor through a mobile app, and integration with demand response programmes allow users to shift energy use to off-peak times, maximising savings and minimising grid strain. Irish households are rapidly adopting smart home technology, with a 50% year-on-year growth in home automation (Enterprise Ireland, 2020).

Starting requirements

Households with stable internet access and basic levels of energy literacy are already well-positioned to invest in smart appliances and their flexible use. Internet connectivity and familiarity with technology are critical for effectively using app-based controls and remote monitoring features (Gumz and Fettermann, 2022). Homeowners are better placed to install and manage smart devices due to greater control over appliances; while renters often face structural constraints and even in the case of the breakdown of a current appliance, landlords replace them with the same model or price range (Rausser et al., 2017). For many households, demand flexibility will be largely driven by smart appliances, which provide a more suitable or affordable alternative for energy users who do not have the financial means to install heat pumps or solar PV.

Trust in technology is an important factor in the adoption of smart appliances, with confidence in the security of personal data and the perceived ease of use being key drivers of engagement. Hedonic motivation—enjoyment derived from interacting with smart technology—combined with a belief in its performance benefits further enhances the willingness to invest in these devices (Gholami et al., 2020). Younger adults (aged 18-40) and women are particularly responsive, motivated by a strong interest in convenience and energy efficiency. Similarly, households with higher energy consumption are driven to adopt smart appliances as a cost-saving strategy through improved efficiency (Gumz and Fettermann, 2022). Finally, environmentally-motivated individuals open to adjusting their energy habits or engaging with tools like in-home displays are more likely to incorporate smart appliances into their routines (Gholami et al., 2020).

Trigger

Triggers for adopting smart appliances often stem from practical needs, such as the breakdown of existing appliances or a desire to upgrade. Acquiring new smart devices with energy-saving features or seeking to simplify and automate household tasks can also prompt exploration. Rising energy costs, awareness of ToU tariffs, and promotions or incentives offered by retailers, manufacturers, or energy providers further encourage consideration.

Barriers

Without immediate triggers, low awareness and poor understanding of how smart appliances work prevent many households from exploring these options. During stressful events like appliance breakdowns, narrow focus and limited mental capacity can hinder decision-making and make people more inclined to stick with what they know.

Potential solutions

- **Incentivise smart-enabled appliances and run campaigns that highlight the associated benefits.** Smart appliances could enable flexibility particularly for energy users whose routines are less flexible, like families, full time workers and those with caring responsibilities (Malatesta and Breadsell, 2022).

SMART APPLIANCE ADOPTION & USE | ROADMAP TO FLEXIBILITY

	TRIGGER	Stage 1 CONSIDERATION & PLANNING	Stage 2 ACTION	Stage 3 SUSTAINING FLEXIBLE BEHAVIOUR
BEHAVIOURS	An energy user must have stable internet access and basic levels of energy literacy to start. Renters have less control over appliance choice than homeowners. The need to replace an existing appliance often acts as a trigger. Rising energy costs combined with awareness of time-of-use tariffs can also encourage users.	Users compare models in terms of cost, potential savings, compatibility with existing home systems. Engaged users may explore flexibility features of appliances such as auto-demand response capability in more detail.	Energy users purchase, install and set up their smart appliance, connecting it their home network. They may enrol their appliance in demand side flexibility or direct load control programme, switch to a flexible tariff or install additional devices like smart hubs.	Energy users optimise their smart appliances for comfort and efficiency. They may need to adjust settings with changes in routines and energy needs. Users may also track usage and savings (e.g. through in-home displays) and learn from this feedback.
BARRIERS	Low awareness Narrow focus during distress purchases	Higher upfront cost Flexibility potential of appliances not considered Complexity aversion	Complexity of installation Unclear instructions for enrolling in demand response programmes	Lack of feedback on performance & savings Waning interest
SOLUTIONS	▶ Incentivise smart enabled appliances and run campaigns that highlight the associated benefits	▶ Position smart devices as enhancers of comfort and energy efficiency ▶ Address concerns about security and loss of control ▶ Educate retail salespeople on the flexibility potential and associated savings of smart appliances	▶ Ensure interoperability standards between smart appliance manufacturers and utility providers ▶ Standardise real-time feedback provided by smart appliances and in-home displays	▶ Create user-friendly dashboards for smart appliances with visual cues ▶ Send personalised notifications based on energy usage ▶ Implement gamification elements

Stage 1: Consideration and planning

During the consideration phase of the adoption of a smart appliance, households explore the potential benefits, such as energy efficiency and cost savings. They compare brands and models, evaluate compatibility with existing home systems, and learn about government or energy provider rebates that could offset purchase costs.

Flexibility-focused energy users may also investigate the flexibility features of smart appliances. This includes learning about auto-demand response capabilities and understanding which manufacturers and energy providers support participation in demand side flexibility and direct load control programmes. They assess the financial and environmental benefits of pairing appliances with dynamic and ToU tariffs, gaining insights into potential savings.

Barriers

Even in the event of breakdown of an existing appliance, higher initial costs of smart appliances and lack of trust in automated technologies can discourage consideration. Some energy users perceive these devices as overly complex and are uncertain about potential benefits. Limited awareness of demand response capabilities, confusion over government incentives, and difficulty comparing models and brands further complicate matters.

People tend to base decisions on the most salient information directly present or available at the time of making the decision—the concreteness principle (Slovic, 1972)—especially in contexts with high degrees of uncertainty. Information that has to be inferred is often not considered. The most salient piece of information when buying a new appliance is generally cost. Demand flexibility information is not usually present and thus not often considered.

Potential solutions

- **Position smart devices as enhancers of comfort and energy efficiency.** For example, smart thermostats can automatically turn off heating when nobody is home and can progressively learn to automatically control the temperature based on the homeowner's habits. Highlighting the increased comfort (for example, through customer testimonials and case studies) might particularly appeal to energy users who are not responsive to other types of benefits, such as saving on energy bills or becoming more energy efficient (Mert et al., 2008). Collaborating with device manufacturers can improve the outreach of such campaigns.
- **Address concerns about security and loss of control.** Some homeowners fear that smart devices share sensitive data, such as energy usage, with manufacturers. Another common concern is that consumers can lose control over devices that operate independently. Ensuring that a simple override capability is always present and that data-sharing policies are transparently communicated can boost smart appliance uptake (Coskun et al., 2018).
- **Educate retail salespeople on the flexibility potential and associated savings of smart appliances**. In their capacity as sources of expertise at the point of purchase, this may help to increase the uptake and subsequent flexible use of smart appliances.

Stage 2: Preparation and installation

This stage involves the actual purchase and installation of the smart appliance. Energy users set up the device for basic functionality and connect it to their home network to enable core features. For flexibility, they perform additional setups of energy-saving modes and schedules. They enrol their appliance in a demand side flexibility or direct load control programme, switch to a time-of-use tariff if applicable, and install additional devices like smart hubs to link the appliance to a home energy management system.

Barriers

Technical challenges often arise during installation, such as difficulties connecting appliances to home networks or setting up energy-saving modes. Unclear instructions for enrolling in demand response programmes and limited support from energy providers exacerbate these issues. The complexity of setup and the need to coordinate with installers can also cause friction in this stage.

Potential solutions

- **Ensure interoperability standards between smart appliance manufacturers and energy providers.** Mandate manufacturers to adhere to interoperability standards such as the Code of Conduct for Energy Smart Appliance (EU Joint Research Centre, 2023) to speed up the development of automated demand side flexibility programmes by energy providers that are compatible with smart appliances.
- **Standardise real-time feedback provided by smart appliances and in-home displays.** Information about appliance consumption and current rates is crucial, particularly for energy users with time-of-use pricing. The CRU is well positioned to enforce the EU Code of Conduct for interoperability (EU Joint Research Centre, 2023) or establish a national standard for smart appliance feedback. Tax rebates or government certifications could be offered to manufacturers who adopt these standards early.

Stage 3: Sustaining flexible behaviour

At last, energy users begin optimising their smart appliances for comfort and efficiency. This includes adjusting settings based on daily routines and energy needs, as well as tracking energy usage and cost savings through in-home displays or apps. "Customers of the future" engage with auto-demand-response events, allowing their appliances to respond automatically to energy provider signals. They monitor participation and savings, reassess settings for greater efficiency, and learn from feedback to refine their usage habits.

Barriers

Sustained flexible use brings a multitude of benefits; however, interest can also easily wane, especially when faced with lower-than-expected savings and difficulty seeing the appliance's individual impact on energy bills. Habitual behaviours, such as using appliances at set times, may prevent optimal use. Limited feedback on the performance of demand response events and a lack of motivation to adjust usage over time further hinder engagement.

Potential solutions

- **Create user-friendly dashboards for smart appliances with visual cues**, such as colour-coded indicators of energy consumption. Simplified graphs and visual representations make the energy data more intuitive for users, helping them better understand the implications of their energy use.
- **Send personalised notifications based on energy usage** to help users plan for peak events in advance. This includes reminders to shift heavy energy use to off-peak periods and alerts about planned demand response events, ideally sent at least 24 hours in advance (Centre for Net Zero, 2023).
- **Implement gamification elements** like energy-saving goals, progress tracking, and small symbolic rewards (for example, points) for achieving set targets to motivate users to stay engaged with their home displays and make sustained changes to their energy habits.

Future directions

Based on the obtained research insights, the following open questions were identified to help drive the adoption and best use of smart appliances:

- How can trust in smart technologies be fostered among non-tech-savvy customers and late adopters who tend to be particularly hesitant about smart appliances?
- How to ensure that smart appliances consider the individual needs of households (for example, different levels of thermal comfort) and adjust the amount of provided energy flexibility appropriately?
- In which contexts can symbolic and environmental rewards motivate users towards greater flexibility as effectively as financial rewards?
- When is the optimal time to promote time-based tariffs to smart appliance adopters—for example, at the start of their adoption journey or after they become familiar with the device?

3.4.2. Heat pump adoption and flexible operation

Ireland's policy framework places significant emphasis on heat pump adoption as a cornerstone of its climate action goals. By 2030, heat pumps are expected to supply 12-20% of the nation's heating demand (SEAI, 2022), with aspirations to install 600,000 units by the same year (SEAI, 2022). Despite these ambitions, adoption remains low—fewer than 8% of Irish homes had a heat pump installed by the end of 2024, and SEAI supported slightly fewer heat pump installations in 2024 than in 2023 (3,600 vs 3,767).

SEAI has previously published a report and roadmap for heat pump uptake (SEAI, 2020b) and conducted research on barriers and drivers of adoption in oil-heated homes (SEAI, 2024a; SEAI, 2024b). Financial, logistical, and informational barriers continue to deter widespread adoption. Upfront costs, installation complexity, and the need for additional work all contribute to these challenges.

Here we focus more specifically on barriers to flexibility that manifest throughout the heat pump journey from consideration to operation. While heat pumps increase the demand for electricity in absolute terms, they offer a sustainable solution if set to use energy in flexible ways, such as by running on moderated settings during peak hours. Their uptake across social groups is important too for equitable access to flexibility opportunities in light of the energy intensity of space heating.

Demand side flexibility through heat pumps is typically implemented alongside a time-based tariff or response programme that issues notices about high demand. It is also possible in principle for the energy provider to control its operation and switch it on or off to suit grid requirements (direct load control). Importantly, Crawley et al. (2022) note that many assumptions in current heat pump modelling ignore user behaviour, while existing empirical work, which is sparse, has shown this is problematic (SEAI, 2022).

Particular flexibility factors that need to be considered early in the journey include the heat pump type. Air-to-water heat pumps can shift demand to off-peak hours when paired with thermal storage like a large hot water tank. In contrast, air-to-air heat pumps lack thermal storage and are less adaptable to demand shifting. Heat pumps are highly heterogenous systems, and often require tailored flexibility mechanisms. More generally, proper system sizing and installation choices, such as investing in thermal storage or integrating smart controls that respond to time-based tariffs, further influence a heat pump’s flexibility. However, without greater awareness of these factors during the adoption stage, many households may not fully leverage the flexibility benefits heat pumps can provide.

Starting requirements

The journey towards heat pump adoption and flexible use is typically most suitable for homeowners whose properties have adequate insulation, such as well-insulated walls, roofs, and floors, or for those willing to invest in retrofitting. Access to sufficient financial resources or affordable financing options, such as grants or low-cost loans, is crucial to cover the significant upfront costs of installation and any necessary retrofitting measures. To make heat pumps more accessible, SEAI offers grants of up to €6,500 for heat pump installations. An additional €200 “Technical Assessment” grant is available. However, financial support alone does not eliminate all barriers to adoption and flexible use.

HEAT PUMP ADOPTION & OPERATION | ROADMAP TO FLEXIBILITY

	TRIGGER	Stage 1 **CONSIDERATION & INSTALLATION**	Stage 2 **SUSTAINING FLEXIBLE BEHAVIOUR**
BEHAVIOURS	Homeowners in adequately insulated homes with sufficient financial resources are best placed to start this journey. Hearing about government incentives can act as a trigger, as can undertaking a broader home renovation or recommendation from family, friends or an energy audit.	Energy users evaluate whether a heat pump is suitable for their home, comparing with alternatives in terms of cost and efficiency. Ideally the flexibility potential of the heat pump and relevant tariffs will factor into people's decision.	To maximise flexibility, heat pump owners can integrate them with smart thermostats and enrol in demand flexibility programmes. Switching to a flexible tariff can help users benefit and keep their running costs down.
BARRIERS	Lack of awareness of heat pumps as a heating system Exposure to misinformation	Lack of understanding of how heat pumps work High upfront cost & uncertainty over long-term performance Lack of awareness of demand flexibility considerations	Complexity of heat pump controls Conflicting advice on optimal operation Lack of specific financial incentives
SOLUTIONS	▶ Run nationwide awareness campaigns based on a thorough understanding of the relevant audience	▶ Educate installers & encourage provision of flexibility advice during installation ▶ Customise outreach strategies to different consumer segments ▶ Offer increased subsidies and trial opportunities	▶ Develop tailored customer outreach programmes to educate owners about the benefits of integrating heat pumps with smart meters and time-based tariffs ▶ Implement performance-linked financial incentives

Trigger

Potential heat pump adopters are often motivated by recent or forthcoming renovation, or increasing energy costs during colder months. Government incentives, such as grants or tax credits, also act as critical triggers by offsetting financial concerns and drawing attention to the potential savings and environmental benefits of heat pumps. Exposure to recommendations from energy audits, professionals, or peers who have successfully adopted heat pumps can further nudge individuals toward adoption. People who already have one begin to use it flexibly when they see some information or hear about time-of-use tariffs.

Barriers

Lack of awareness of heat pumps or misconstruing them as a component of another heating system as opposed to systems in their own right, would naturally dampen any effects of the triggers above. The proliferation of misinformation about heat pumps is also bound to harm adoption rates (Rosenow, 2024).

Potential solutions

- **Run nationwide awareness campaigns based on a thorough understanding of the relevant audience**, their worldview, and wider influences on their beliefs (UK Government, 2022) to address misconceptions and highlight benefits, such as comfort and long-term savings. Encourage energy providers and trusted local messengers (for example, installers) to support these efforts to enhance uptake (Strazzera et al, 2024).

Stage 1: Consideration and installation

In the first phase, potential adopters evaluate whether heat pumps are suitable for their homes and begin comparing them with their current systems in terms of cost, efficiency, and flexibility. They research heat pump models, consult installers and conduct technical assessments to ascertain property suitability and explore financing options.

Relevant factors to consider for flexibility include the type of heat pump that will be installed. As noted earlier, air-to-water heat pumps are more amenable than air-to-air in that they can be paired with thermal storage like a large hot water tank. Thinking ahead at this stage about installation choices such as these, as well as integrating smart controls that respond to time-of-use tariffs, is important.

Barriers

Many individuals have limited awareness of how heat pumps work, leading to confusion, misinformation, and the spread of common myths, such as that heat pumps are unsuitable for older properties or are ineffective in freezing temperatures. Many people, especially if switching from a fossil fuel boiler, will simply be unaware of demand side flexibility and it will not feature in their decision making. Additionally, individuals with busy schedules—who might otherwise be in a suitable financial position—may lack the mental capacity to thoroughly evaluate heat pumps. The high upfront costs and uncertainty about their long-term performance also contribute to hesitation.

Potential solutions

- **Educate installers and encourage provision of flexibility advice during installation.** Integrate flexibility information into certification and training for installers on technical skills and effective consumer communication; this will enhance trust in heat pump technologies, ensure high-quality installations, and increase the likelihood of flexible use (Mukherjee et al., 2020; Strazzera et al., 2024).
- **Customise outreach strategies to different consumer segments** (for example, younger, environmentally-conscious individuals or hesitant older homeowners). Promising strategies for promoting low-carbon technologies include public statements that fossil-fuel boilers will be phased out after a given date, as well as the fact that the amount of grant support will decrease with time (Klein and Deissenroth, 2017). Similarly, emphasise comfort and wellbeing in public information campaigns, focusing on the consistency of heating and air quality benefits of heat pumps, especially for older homeowners (Mukherjee et al., 2020).
- **Offer increased subsidies and trial opportunities**, particularly for vulnerable households, to make heat pump adoption more financially feasible and build trust in the technology (Strazzera et al., 2024).

Stage 2: Flexible use

To maximise the flexibility of heat pumps, energy users can integrate them with smart thermostats, switch to time-based tariffs, and enrol in additional demand side flexibility programmes.

Barriers

Users can struggle to programme heat pumps for maximum efficiency due to the complexity of available tools. Limited access to smart devices or integration systems can restrict the ability to automate flexibility.

Many existing heat pump owners in Ireland are not on energy tariffs that promote flexibility. While all major Irish energy providers offer day/night tariffs and day/peak/night time-based tariffs suitable for (though not specific to) heat pump owners, their uptake remains low. Consequently, while financial incentives and evolving energy tariffs present opportunities to enhance heat pump uptake and flexibility, key challenges remain in ensuring that homeowners can take full advantage of these benefits. Moreover, trust issues related to data privacy and hesitancy to rely on automated systems may deter participation in demand side flexibility programmes.

Another important barrier is that most advice on heat pumps recommends running them continuously or for extended periods to maximise efficiency, which is at odds with curtailing use at peak hours. Consumers thus must make a trade-off that involves complex calculations unless clear and substantial flexibility incentives are available. In addition, unforeseen or unintended outcomes of heat pump flexibility can reduce comfort. For example, a UK trial in which operation was automated in response to price signals and pre-warmed the building in advance of lower settings being implemented, building temperatures (and noise levels) ended up being too high and energy consumption increased, partly due to occupants intervening in control settings (Sweetnam et al., 2019).

Potential solutions

- **Develop tailored customer outreach programmes to educate owners about the benefits of integrating heat pumps with smart meters and time-based tariffs,** ensuring that customers understand how they can best operate their heat pump to maximise savings (Expert interview).
- **Implement performance-linked financial incentives** that reward participation in demand side flexibility programmes, such as energy bill rebates tied to reduced peak-time consumption (Mukherjee et al., 2020; Strazzera et al., 2024).

Future directions

The following future research questions are proposed to support the adoption and optimal use of heat pumps:

- How can user training and support systems be designed to ensure optimal heat pump usage in line with the needs of the grid?
- To what extent can type-of-use tariffs (i.e., reduced electricity rates for heat pump owners during off-peak times) drive additional heat pump uptake?
- How to ensure that heat pump automation is set up to account for varying user preferences, such as prioritising comfort over savings or vice versa?
- What early-stage interventions, beyond local heat pump demonstrations, are most effective in addressing common misconceptions about heat pump performance and costs.

3.4.3. Electric vehicle adoption and flexible use roadmap

As part of the plan to decarbonise the transport sector, the Government of Ireland (GOI) has ambitious goals to transition from internal combustion engine (ICE) vehicles to electric vehicles (EVs) (GOI, 2023). This switch will greatly increase electricity demand, including during existing peak times as some EV owners prefer to charge at home in the evening (Morrissey et al., 2016); and may produce new local consumption peaks (McKinney et al., 2023).

Approximately 80% of charging events in Ireland occur at home (SEAI, 2025a); the workplace is the next most popular charging point, followed by public locations (Hardman et al., 2018). Recent research for SEAI found that the vast majority of EV owners live in semi- or detached homes with access to their own charging point, and predominantly charge overnight. Recent SEAI data is in line with these figures and suggests that approximately 6% of EV owners charged during the evening peak time (SEAI, 2025a).

Nonetheless, charging demand flexibility will be increasingly important if highly ambitious EV adoption targets are met, not only for maximising the use of renewables, but for minimising additional grid pressures.
One way to incentivise off-peak charging is time-based tariffs (see section 3.3. for electricity tariff switching roadmap). EV-specific tariffs with low rates typically between 2am and 5am are available from several suppliers in Ireland. The price differentials tend to be much larger than typical ToU tariffs without early morning specific rates, and charging time has been shown to correlate strongly with ToU rates for those who avail of them, indicating good efficacy (Kim, 2019). Recent research for SEAI found that only a quarter of EV owners are on EV-specific tariffs (though another 35% are on night-saver tariffs).

Smart charging is another (and complementary) mechanism to reduce the grid pressure that EVs cause and maximise the use of renewable energy. Unlike conventional chargers, smart chargers have the ability to act on real-time grid data to align charging time with grid status, as well as to connect to devices such as smartphones, and directly to energy providers. Thus, charging can be optimised to coincide with times of cheapest rates and lowest grid emissions—either by the owner or the utility. The charger can also be set to align with solar generation systems in the household or business premises. Additionally, grid pressure is minimised because generally, rather than charging at full power straight from plug in, smart chargers charge the EV at variable power rates that align with real-time demand. This often results in longer charging sessions compared to conventional charging. In the UK, regulation stipulates that all new EV chargers must have smart capabilities. In Ireland, the SEAI grant for EV chargers only supports smart versions. To explore and support EV charging flexibility, ESBN and FlexCharging are currently conducting a 12-month proof of concept project, using vehicle telematics to manage charging schedules and optimise grid demand. The project aims to assess flexible capacity, analyse EV demand response, and inform the development of a new smart charging flexibility product in 2025 (ESBN, 2024).

Some EVs are capable, not only of drawing power into their battery, but of outputting power from it, whether that be to the grid (Vehicle-to-Grid; V2G), to a home or other building, or to appliances or equipment. Vehicle-to-everything (V2X) is the umbrella term. Storing energy in the vehicle battery for later alternative uses can provide significant flexibility. In this sense, at the same time that it causes the need for demand side flexibility, the uptake of EVs is an enabler of future demand side flexibility.

SEAI published a report on behavioural barriers to EV uptake in 2020, identifying hyperbolic discounting (a bias towards smaller more immediate rewards over larger delayed ones), status quo bias, and knowledge gaps, in addition to high costs and range anxiety as primary barriers to uptake (SEAI, 2020a). Despite advancements in EV technology and price reductions, cost remains a primary barrier, cited by 50% of survey respondents as the main reason for hesitating to switch to EVs (O'Neill et al., 2024). Concerns about battery health and range, misinformation about EV performance, and inadequate charging infrastructure further compound the challenges. Government grants for new battery EV purchases were decreased from €5,000 to €3,500 in 2023, with funds redirected to support charging infrastructure development. The Home Charger Grant of up to €600 is available for installation of a home charging point.

More germane to current interests are V2G schemes. Schemes and analyses from pilots conducted in other European countries have shown double taxation on stored energy, inconsistent market access, and complex technical requirements are notable barriers (SmartEN and DNV, 2024). A report by SCALE (Smart Charging Alignment for Europe), a Horizon Europe project testing and validating a variety of smart charging and V2X solutions in seven countries, found that consumer participation in V2X and V2G schemes is driven by financial incentives, sustainability, and grid stability—but concerns over control, battery degradation, and charge reliability remain. Generally, EV owners express high willingness to engage in V2X solutions and maximise self-consumption. Many already engage in smart charging by shifting to off-peak hours.

The report highlights the importance of trust in third-party management and clear user benefits as key factors in increasing flexible charging adoption (SCALE, 2022).

The roadmap outlines the journey from considering an EV purchase to installing and flexibly operating a home charger, emphasising maximising flexibility through tariffs, automation, demand response programmes, and everyday habits.

Starting requirements

Purchasing an EV requires significant financial resources and infrastructural support. Financially, individuals need to afford the higher upfront cost of EVs or access subsidies—including those from employers—or affordable financing options. Infrastructure requirements include access to off-street parking or reliable public charging networks.

Certain demographic and professional groups are more inclined to adopt EVs and embrace their flexible use. Men tend to exhibit stronger intentions toward EV adoption, potentially due to a heightened interest in technology and vehicles (Li et al., 2017). Young and middle-aged energy users are also more likely to adopt EVs, driven by their openness to innovation and evolving mobility preferences. This trend is especially pronounced among Millennials and Gen Z, who represent 70% of the new wave of EV buyers in western Europe (France, Germany, Italy, Spain, and the UK). These younger adopters are predominantly urban (75% live in cities), highly educated (85% hold university degrees), and value speed, advanced digital features, sustainability, and seamless brand experiences (Pannier et al., 2024). Moreover, energy users working in technical professions show a marked preference for EVs, likely due to their familiarity with and enthusiasm for cutting-edge technologies. Early adopters also tend to reside in urban or suburban areas, where robust charging infrastructure and supportive policies facilitate EV use.

Trigger

Triggers for EV adoption include needing to replace another vehicle; rising petrol and diesel costs or increased awareness of emissions; and awareness of government grants or subsidies. The introduction of low-emission zones and incentives offered by employers also prompt households to consider EVs. Social proof, such as friends or neighbours adopting EVs, and exposure to advertising campaigns by manufacturers, energy providers, or retailers often spark interest. Technological advancements, such as new EV models with improved range and features, and situational changes, such as moving to a home with charging capabilities, also act as motivators. A recent shift toward conscious energy consumption within the household, including generating and storing electricity at home can further support interest in EVs. Learning of the potential for flexibility through smart charging, tariffs, and V2G might also be a trigger.

Barriers

Many households lack awareness of available EV models, especially in lower price ranges. Poor understanding of EV charging infrastructure, concerns about range (range anxiety), and uncertainty about long-term reliability deter adoption. A perceived lack of urgency and reluctance to replace an ageing vehicle without immediate need exacerbates hesitation.

Potential solutions

- **Consider expanding financial incentives, specifically targeting regions of high car-dependence**, which are primarily rural. Incentives help address the high upfront costs associated with EVs and are crucial for encouraging adoption, particularly among middle-income households (Li et al., 2017; Singh et al., 2020) and could be targeted to areas of high car-dependence.

EV ADOPTION & CHARGING | ROADMAP TO FLEXIBILITY

	TRIGGER	Stage 1 CONSIDERATION & INSTALLATION	Stage 2 SUSTAINING FLEXIBLE BEHAVIOUR
BEHAVIOURS	Energy users need significant financial resources to purchase an EV. Access to off-street parking or reliable public charging is also required. Hearing about government incentives can act as a trigger, as can the need to replace an existing vehicle, peers adopting an EV, moving to a new home with a charger or rising fuel prices.	Energy users research the benefits and drawbacks of EVs, comparing different models and considering the feasibility of setting up home charging. Ideally, flexibility considerations will also feed into people's decisions (e.g. opting for a smart charger, researching EV tariffs).	EV owners adjust their charging routines for maximum efficiency and may participate in demand-response and vehicle-to-grid schemes. They may consider installing additional technologies such as solar PV to enhance self-sufficiency.
BARRIERS	▌ Lack of awareness of available EV models ▌ Reluctance to replace existing vehicle without immediate need	▌ High perceived cost & lack of awareness of financial benefits ▌ Range anxiety & uncertainty about home charging ▌ Information overload about models, chargers & tariffs	▌ Lack of awareness of flexible charging and vehicle-to-grid ▌ Conflicting charging goals (speed vs. flexibility) ▌ Poor understanding of battery percentages
SOLUTIONS	▶ Consider expanding financial incentives, specifically targeting regions of high car-dependence	▶ Address energy users' range anxiety ▶ Promote the additional savings available through EV-specific tariffs ▶ Introduce regulation to mandate that EV chargers have smart functionality	▶ Forefront range information in mileage rather battery percentage ▶ Emphasise the environmental benefits of switching to an EV & flexible charging ▶ Programme EV chargers to operate outside peak hours by default

Stage 1: Consideration and installation

When considering an EV, prospective buyers begin researching the environmental, cost and other benefits of EVs. They compare models and features, explore available subsidies, tax incentives, and grants, and assess the availability of local charging stations. They also evaluate the feasibility of setting up home charging solutions and compatibility with their living arrangements. Ideally, they also investigate the potential for flexible use of EVs, learning about EV-specific tariffs, demand-response schemes and the role of smart home EV chargers in optimising electricity usage are key focus areas.

When an EV is purchased, owners connect it to a (smart) home charging setup – if they have one. EV owners can then enrol in EV-specific tariffs and set up automated overnight charging schedules. Integrating the EV into any existing low-carbon technologies, such as solar panels and battery storage, are further options for owners of relevant technology.

Barriers

For the majority of households, (perceptions of) high upfront costs of EVs and limited awareness of financial benefits often rule out consideration. Households may also perceive EV technology as unproven or "too new," while misperceptions about range, public charging infrastructure availability and the complexity of understanding tariffs and schemes increase the hesitation even further. Reliable information and advice can also be difficult to find, further complicating consideration.

Information overload about EV models, chargers, and tariffs can overwhelm households. Uncertainty about home charging compatibility, limited access to grants or financing and lengthy application processes further complicate and slow down preparation. Additional costs, such as smart chargers, can also be demotivating. Standard flat tariffs tend to be preferred over time-based tarriffs, which is likely to be in part due to their relative simplicity (Vissaria et al., 2022). Users may have trouble trading off reduced EV charging costs against increased household electricity costs if day rates of the EV tariffs are higher than their existing flat rate.

Technical challenges during installation, such as compatibility concerns between chargers and vehicles, often arise. The time-consuming nature of the installation process and insufficient support for troubleshooting issues add to the frustration.

Potential solutions

- **Address energy users' range anxiety.** Many potential EV buyers are concerned about the insufficient number of charging stations, particularly in rural areas. Helping energy users understand the range of EVs after a single charge as well as sharing plans about expanding the public charging infrastructure can address range anxiety and make EV adoption more appealing for a wider population, especially outside major urban centres (Li et al., 2017).
- **Promote the additional savings available through EV-specific tariffs.** EV dealers can educate prospective buyers and promote EV tariffs as a way to optimise their usage and reduce their energy bills. EV tariffs can provide strong financial incentives for energy users to charge an EV at low-carbon, low-demand times, helping to balance the grid (Daneshzand et al., 2023).
- **Introduce regulation to mandate that EV chargers have smart functionality**. Currently, the SEAI charger grant only supports smart chargers but regulation, like that in place in the UK, will ensure that people who do not go through the grant also have charging flexibility capacity.

Stage 2: Sustaining flexible behaviour

In the final stage towards electricity demand flexibility, households adjust their charging routines for maximum efficiency. This includes tracking charging data and setting up smart charging that does not necessarily operate steadily at maximum power but rather responds to information from the grid, as well as driving profiles. Drivers might explore additional technologies, such as solar panels, to enhance self-sufficiency. At some point, users also participate in demand response and vehicle-to-grid schemes, enabling their EV to support grid stability and reviewing their data and feedback to refine their charging habits.

Barriers

The first likely barrier to flexible charging is lack of awareness of the benefits of doing so. A previous evidence review found that fleet managers focus on procuring EVs, but not yet on charging them optimally (Energy Savings Trust, 2024). Often, they do not immediately see how it would work or benefit the business.

People might also be put off flexible charging by the apparent complexity and novel technology required. The nature of smart charging might appear to conflict with other charging goals too—for example, smart charging generally takes longer than conventional charging. Contexts of complexity and conflicting goals are particularly susceptible to the use of heuristics and to biased decision making (Tversky and Kahneman, 1974), for example, persisting with default settings or existing ways of doing things.

One relevant heuristic is the numerosity heuristic, which is when attention is given only to the numerical value (number of units) in a piece of information without considering the unit and meaning (the size of the units) (Pelham et al., 1994; Pandelaere et al., 2011)—for example, a 25% battery charge is more than sufficient for most small journeys (Pasaoglu et al., 2012), but instead of thinking about how many miles of driving it affords, people will tend to focus on the fact that 25 is a small percentage. Indeed, people have been shown to tend towards overestimation of the importance of battery charge level in percentage terms when setting charging preferences, resulting in failure to take sufficient account of the available distance range in miles or kilometres (Lagomarsino et al., 2022). Low battery percentages are thus sometimes inaccurately taken to signal insufficient range, leading to unnecessary charging that may also be more likely to be conventional rather than smart if time is an issue (de Sa et al., 2023).

Lastly, limited financial incentives and fatigue from managing settings can decrease engagement over time.

Potential solutions

- **Forefront range information in mileage rather than battery percentage**, and tailor information based on individual driving profiles. This has been shown to correct bias towards overestimating importance of battery percentage charge and increase likelihood of choosing smart charging (Lagomarsino et al., 2022).
- **Emphasise the environmental benefits of switching to an EV and flexible charging** to promote positive spillover effects. Research has shown that positive spillover effects such as flexible charging post-EV adoption are more likely among people with higher environmental self-identity (Peters et al., 2018; de Sa et al., 2023).
- **Programme EV chargers to operate outside peak hours by default**. Off-peak charging is expected to be essential in the future as the number of EV owners and energy demand increases. To reduce interference of cognitive barriers, EV chargers should be programmed for such settings by default, and energy users should be made aware by energy providers of why off-peak charging is essential to ensure a stable grid (Tirunagari et al., 2022).

Future directions

The stakeholder interviews and literature review highlighted several gaps in the existing evidence. These gaps include the following questions:

- What are the most compelling incentives to encourage participation in V2G programs? Should they be financial, symbolic, or tied to environmental impact?
- How can the use of EV batteries for powering households be simplified to ensure widespread adoption and ease of use for all energy users?
- How can consistent and energy-efficient charging habits be encouraged to align with off-peak times, especially for new EV owners?
- Who are the best messengers to alleviate concerns around range anxiety and the lack of charging infrastructure? For example, would peer endorsements, trusted industry voices, or community leaders be most effective?

3.4.4. Solar photovoltaic adoption and flexible use roadmap

Solar photovoltaic (PV) systems offer energy users a sustainable and cost-effective source of energy, combining the benefits of renewable electricity generation with flexible usage. By installing solar PV systems and integrating features like battery storage or grid export capabilities, energy users can reduce reliance on grid electricity and even feed energy back into the grid—resulting in a positive impact on grid stress while lowering energy costs. Aligning energy consumption with peak solar production times, participating in demand response programmes, and optimising energy use through automation can further maximise financial savings and environmental impact (Ryan et al., 2023).

Ireland's policy framework prioritises solar PV adoption as a critical element of its renewable energy strategy. The Climate Action Plan targets 2.5 GW of rooftop solar PV capacity by 2030, with current capacity reaching approximately 680 MWp as of mid-2023. In 2024, there was a 25% increase in solar panel systems installed in Ireland, with some 29,151 installations across the country (Energy Efficiency Ireland, 2025).

To boost adoption, SEAI offers grants of up to €1,800 for solar PV systems. Since 2022, Irish homeowners have been eligible to sell their surplus solar electricity to the grid at prices negotiated between energy providers and energy users. There is currently no dedicated grant for battery storage—limiting homeowners' ability to store excess solar energy for later use. Other schemes include The Micro-generation Support Scheme, which provides financial incentives for non-residential systems up to 1 MWp, and the Solar Capital Investment Scheme supporting agricultural settings. Additional measures include the Clean Export Guarantee (CEG), allowing homeowners to sell excess electricity back to the grid, and a VAT reduction on solar installations (SEAI, 2023b). Recent Budget 2024 initiatives increased the Clean Export Guarantee tax disregard to €400 to further support adoption. To further support the transition, mandatory solar requirements are also being introduced; from 2026, all new commercial and public buildings over $250m^2$ will require solar PV installations. Similar mandates will apply to existing buildings during the third carbon budget period (2031-2035). This comprehensive mix of grants, mandates, and incentives aims to overcome barriers and accelerate the transition toward its renewable energy goals (Ryan et al., 2023).

Starting requirements

Installing solar PV requires a certain physical and financial capacity. While in some cases, renters may be able to liaise with landlords to install solar panels, individuals who own their homes have greater control over making structural modifications. Suitable housing (such as detached or semi-detached homes with adequate roof space and proper orientation) is also essential for installation feasibility. Access to capital or financial incentives (such as savings, government grants, subsidies, or low-interest financing) helps overcome the significant upfront cost barrier. Finally, basic awareness and motivation play a crucial role; individuals with access to information about the benefits of solar PV systems and an interest in energy savings or sustainability are more likely to take the first steps.

Higher-income households are better positioned to afford the substantial upfront investment required for solar PV systems and battery storage, making wealth a key driver of adoption (Curtin et al., 2019). Similarly, highly-educated individuals are more likely to adopt these technologies, as education enhances awareness of renewable energy benefits (Mukherjee et al., 2020). Rural and suburban homeowners also show higher adoption rates, as detached homes in less densely populated areas are structurally more suitable for installations, and rural homeowners tend to have greater awareness of solar PV systems (Claudy et al., 2010). Environmentally-proactive groups are another important segment, motivated by a belief in the significant impact their individual actions can have on climate change, even though environmental attitudes alone are not strong predictors of adoption (Mukherjee et al., 2020). Finally, newer homeowners in modern housing are more inclined to install solar PV systems because recently built homes often meet the structural and electrical requirements for installation and are more energy-efficient, which enhances the return on investment (McIntyre et al., 2021).

SOLAR PV ADOPTION & USE | ROADMAP TO FLEXIBILITY

	TRIGGER	Stage 1 CONSIDERATION & PLANNING	Stage 2 ACTION	Stage 3 SUSTAINING FLEXIBLE BEHAVIOUR
BEHAVIOURS	Homeowners with suitable roof space and sufficient financial resources are best placed to start this journey. Becoming aware of decreasing installation costs or government incentives can be a trigger, as can seeing others installing the technology. Renovating the home can also prompt consideration.	Energy users begin researching the benefits of solar PV, compare different providers and investigate financing options. As part of this process they may consider the potential for solar PV to enhance flexibility and the opportunity presented by flexible tariffs, feed-in tariffs and battery storage.	Once they decide to proceed, energy users consult with experts to determine optimal system size and panel placement. Ideally, they also install battery storage to maximise their flexibility potential. Once installed, users set up basic solar energy monitoring tools and connect the system to the grid to meter or export surplus energy.	Once the system is operational Users continue to monitor their electricity generation and usage patterns, adjusting their behaviour and appliance settings for maximum efficiency. Some users may automate appliance usage to align with solar production hours or participate in demand response events using stored energy.
BARRIERS	Perceived high upfront cost & lack of awareness of incentives Lack of awareness of ability to sell back to grid	Information overload & lack of clarity on return on investment Low trust in providers Concerns about legislation & permissions	Complexity of installation Lack of awareness of flexibility benefits of battery storage Limited installer availability & support	Lower than expected savings Habits overriding automated settings Conflicting advice on best time to use electricity
SOLUTIONS	▶ Expand access to solar through community-based and shared ownership models	▶ Provide grants and subsidies specifically aimed at low-income households ▶ Develop specific policies for solar PV adoption in multi-unit residential buildings, such as shared PV systems for apartments	▶ Promote battery storage as a key component of solar PV investments ▶ Promote installer training programmes that focus on provision of expert accurate advice to the public	▶ Encourage in-home-display set-up alongside PV installation ▶ Introduce tariffs that benefit customers who use battery storage alongside solar PV ▶ Integrate provision of demand flexibility information into the grant approval process

Trigger

The decision to explore solar PV systems is often triggered by households becoming aware of the decreasing costs of solar technology or the ability to sell back to the grid and be less dependent on it. Rising electricity bills, government incentives, and tax breaks further motivate households to consider adoption. Positive experiences shared by friends, neighbours, or community members create social proof, while home renovations provide an ideal opportunity for upgrades.

Barriers

Perceived high upfront costs, limited knowledge of government incentives, and uncertainty about long-term financial returns discourage adoption. Households may fear maintenance costs or installation complexities, while a lack of trust in solar providers or contractors may undermine confidence. Additionally, some households are unaware of the opportunity to sell surplus energy altogether or reduce their dependency on the national grid.

Potential solutions

- **Expand access to solar through community-based and shared ownership models**. While solar grant uptake is already very high, supporting solar projects in community buildings, especially in rural areas, would have direct benefit to communities while also working to help local individuals learn about costs, grants, and functionality through seeing it work in their locality—ultimately enhancing local buy-in through highly-visible social norms (Curtin et al., 2019).

Stage 1: Consideration and planning

During the consideration stage, energy users begin researching the benefits of solar PV systems. They compare providers, products, and features to evaluate which system best suits their needs. Learning about available subsidies, tax incentives, grants, and financing options is an essential component of this phase, as is understanding system compatibility with existing home infrastructure.

This stage also provides a good opportunity for households to explore how solar PV systems can be used flexibly to maximise benefits. This includes learning about time-based tariffs, Feed-in Tariffs (FIT), and schemes that allow them to sell surplus energy back to the grid. They may also investigate smart home technologies that integrate with solar PV systems to optimise energy usage and assess the potential savings from pairing solar panels with battery storage.

Barriers

High upfront costs remain a significant deterrent, compounded by information overload and a lack of clarity about financial benefits. Many households are uncertain about the economic returns on investment, grant eligibility, and the perceived hassle of maintaining solar PV systems. Concerns about legislation, permissions, and system compatibility with existing home infrastructure further complicate progress. Trust in provider claims and incentives is often low, leading to further hesitation.

Potential solutions

- **Provide grants and subsidies specifically aimed at low-income households** to promote equitable access to solar PV installations. Financial support can help overcome high upfront costs that are a major barrier for economically disadvantaged groups. An example is Australia's Solar for Low-Income Households Program that provides up to 50% subsidy of total solar system cost for qualified low-income households (Ryan et al., 2023). Similarly, SEAI's grant system could be expanded to provide higher grants for households below a defined income threshold.
- **Develop specific policies for solar PV adoption in multi-unit residential buildings, such as shared PV systems for apartments**. This is particularly important in cities where roof space is shared among multiple owners, and individual adoption can be challenging. For example, a one-stop shop for energy improvements specifically designed for multi-family buildings is being developed in the Baltic countries (Ryan et al., 2023; RenoWave, 2023).

Stage 2: Preparation and installation

Energy users consult with experts to determine optimal system size and panel placement and decide whether or not to install battery storage.

Once the system is installed, owners set up solar energy monitoring tools and connect the system to the grid to meter or export surplus energy. To enable flexible use, energy users may also install smart devices and schedulers that optimise solar electricity usage. Scheduling appliances to operate during peak solar production hours and integrating the system with home energy management tools are essential actions at this stage.

Barriers

The preparation stage is often hindered by a lack of qualified installers and uncertainty about additional costs for batteries or smart appliances. Challenges in assessing programme eligibility or home infrastructure compatibility also often arise. Finding adequate space can sometimes be a barrier. Larger installations (over 12 m^2 and covering 50% of the roof) require planning permission. Limited information and support from providers during this stage, coupled with difficulties evaluating long-term savings, create further friction and decrease motivation. Many people are simply unaware of the benefits of batteries for flexibility and thus do not consider them.

Technical challenges during installation, such as difficulties connecting the system to the grid, are common. The complexity of setting up energy-saving modes and integrating with demand side flexibility programmes can be daunting, heightened by the limited installer knowledge about demand response integration and unclear instruction. Additionally, energy users must also accommodate installation timelines, which can disrupt daily routines.

Potential solutions

- **Promote battery storage as a key component of solar PV investments**, capitalising on the moment of transition among homeowners who are in the process of installing a solar system (Ryan et al., 2023). Expand SEAI's grant programs to provide financial incentives for households that install both solar PV and battery storage.
- **Promote installer training programmes that focus on provision of expert accurate advice to the public** (including the demand side flexibility aspects of solar technology) as opposed to solely on technical aspects of installations.

Stage 3: Sustaining flexible behaviour

Once operational, energy users monitor their electricity generation and usage patterns, adjusting their behaviour and appliance settings for maximum efficiency. Tracking cost savings through in-home displays or apps and evaluating the environmental impact of their solar PV system are key behaviours. Energy users may also actively automate appliance usage to align with solar production hours and participate in demand response events using stored solar energy, if available.

Barriers

Despite some of the immediate benefits, users face challenges in achieving sustained, flexible use. Savings may be lower than expected, and the impact of solar PV systems on overall bills may not be immediately clear. Habits, such as fixed appliance usage times, can also often override automated settings, limiting optimisation. Confusion may arise from conflicting messaging in advice on when is a good time to use electricity—for those without solar PV, running appliance late at night or in the morning is generally better, while for those with solar, the best time for electricity use is generally during the day.

Potential solutions

- **Encourage in-home display set up alongside PV installation** so that users can easily track generation and consumption.
- **Introduce tariffs that benefit customers who use battery storage alongside solar PV**, optimising their energy costs and promoting self-consumption (Expert interview).
- **Integrate provision of demand flexibility information into the grant approval process** so that people are aware of how best to use their new technology to the benefit of the grid and themselves.

Future directions

The following research questions to support the adoption and optimal use of solar photovoltaic systems emerged during the stakeholder interviews and evidence review:

- What are the most effective ways to facilitate communication among different households to support collective PV adoption?
- How can PV owners be encouraged to maximise self-consumption during solar generation hours instead of feeding excess power into the grid, particularly during periods of grid overload?
- What are the most effective incentives to promote joint PV and battery installations? For example, to what extent can additional one-off discounts and battery-centred type-of-use tariffs drive additional battery installations?

4. Conclusions

This report presents how behavioural insights can drive greater demand flexibility among Irish households and SMEs—key players in Ireland's energy transition. By applying these insights, policymakers can develop effective initiatives to alleviate grid strain, support wider utilisation of renewable energy, and achieve national climate targets.

The behavioural taxonomy presented in this report provides a systematic framework for categorising energy flexibility behaviours based on their frequency, cognitive and physical effort, and financial cost. It identifies the resources, agents, and interventions necessary to promote these behaviours. Complementing the taxonomy, the roadmaps outline practical steps for adopting flexibility-enabling technologies (for example, EVs, heat pumps), engaging with time-based tariffs, and embedding flexibility behaviours into daily routines.

Our recommendations emphasise the need for coordinated action on multiple levels: improved awareness and communication (for example, educating energy users about their role in demand response through targeted campaigns); simplification (for example, streamlining smart tariff offerings to make them more accessible and user-friendly); incentivisation (for example, offering discounts on purchasing smart appliances pre-enrolled in demand response programmes); infrastructure development (for example; enhancing the interoperability of smart appliances and home energy management systems); and community engagement (for example, building networks to connect prospective low-carbon technology buyers with existing owners).

These strategies offer a clear pathway toward achieving the Department of the Environment, Climate and Communications' 20-30% national demand flexibility target by 2030. By implementing these insights, policymakers can empower Irish energy users to actively participate in the energy transition, contributing to grid stability, reduced emissions, and lower energy costs.

Glossary

Behavioural barriers: psychological, social, or contextual factors that hinder adoption of desired behaviours, such as lack of awareness, resistance to change, or misconceptions about the benefits of energy demand flexibility.

Behavioural enablers: factors or conditions that facilitate or motivate individuals to adopt desired behaviours. These may include incentives, clear information, social norms, or user-friendly technologies that encourage participation in energy demand flexibility initiatives.

Behavioural intervention: a strategy or action designed to influence consumer behaviour in a specific way, such as encouraging energy-saving practices or participation in demand response programmes, often using insights from behavioural science.

Behavioural taxonomy: a systematic classification of behaviours based on their characteristics, barriers and drivers.

Behaviour change roadmap: a structured plan that outlines the actions, behavioural barriers and policy recommendations for influencing and supporting individuals or groups to adopt desired behaviours.

Direct load control: an arrangement in which an energy provider (or system operator) remotely manages a customer's electrical appliance to turn it off or down to manage grid pressure, typically in exchange for a financial incentive, and usually with an option to override.

Distribution system operator (DSO): a company responsible for managing and maintaining the electricity distribution network – in Ireland, it's the Electricity Supply Board Networks (ESBN).

Electricity demand: the amount of energy currently needed to power human activity. The rate of demand varies considerably across time of year and time of day.

Electricity demand flexibility: the ability of energy users to adjust their electricity usage patterns in response to external signals (such as changes in electricity prices, incentives, or requests from grid operators) to improve efficiency and grid stability.

Electricity demand flexibility enabling technologies: devices and appliances that enable or enhance the flexibility of electricity demand, including smart meters, programmable thermostats, energy management systems, and smart appliances with demand response capabilities.

Electricity demand flexibility services and programmes: initiatives designed to encourage or facilitate electricity demand flexibility. These may include time-based tariffs, dynamic pricing schemes, demand response programmes, or incentives for energy users to shift or reduce electricity usage during peak demand periods.

Energy provider: utility/power companies engaged in generation and distribution of electricity to homes and businesses.

Peak demand: periods of time when energy demand is high. Typically, the largest peaks occur in the evening between 4pm and 8pm, approximately.

Renewable energy: energy derived from natural resources and processes that are constantly replenished, for example, sunlight and wind.

Smart appliance: an appliance that has internet connectivity to afford remote control and monitoring.

Smart energy: a broad term for the use of technology in the management of energy production, distribution, storage, and consumption.

Smart meters: meters with wireless network connectivity to enable remote data sharing functionality.

Time-based tariffs: energy tariffs that are structured so that the price consumers pay for electricity varies by time of day or week. These include static *time-of-use tariffs* which have set prices for predefined time bands, and *dynamic tariffs* which update frequently to reflect wholesale prices.

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