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Factors Influencing People's Willingness to Shift Their Electricity Consumption

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Abstract
As the share of renewable energy sources, which are weather dependent and consequently volatile, continues to grow, it becomes increasingly important to explore strategies for organising both electricity production and consumption to ensure system stability. People's flexibility in their energy consumption is one option to regulate the system. To better understand people's willingness to align their electricity-consuming activities with a flexible pricing system, an online survey with 962 respondents was conducted. The analysis focused on the factors influencing their willingness to shift electricity-consuming activities away from peak hours, as well as the maximum shift duration of using certain devices. The results indicate that people with more flexible lifestyles and those who perceive shifting activities as taking less effort are more willing to shift their activities and indicate longer shift durations. The data also show that attitudes towards the environment, as well as financial, ecological, and motivational factors, play a role in explaining the variance in the willingness to shift and the shift duration. To conclude, increasing flexibility in everyday life could make a valuable contribution to the optimal use of electricity resources.

Keywords Electricity price · Flexibility · Shifting · Lifestyle · Effort

Highlights
- Willingness and duration to shift device use is device dependent.
- Higher perceived effort is related to less willingness to shift and shift duration.
- Perceived lifestyle compatibility is predicting willingness to shift and shift duration.

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Introduction

When people are cold, they turn on the heat; when they are hungry, they cook and eat. Because of socialization, large groups of people often have similar habits and daily household routines, all using similar equipment. This simultaneity in activities leads to peak hours in electricity consumption, meaning the points in time when above-average amounts of electricity are used. In Switzerland, as in most other European countries, one-third of the demand-side electricity consumption comes from private households. In this study, we focused on the consumers in private households to determine their willingness to shift their energy-consuming at-home activities when the electricity price rises. Specifically, we aimed to study people's willingness to shift at-home activities from peak to off-peak hours and the shift duration of using different devices. We explored different factors (e.g., energy-saving behaviour, lifestyle compatibility, perceived effort to shift) that could influence people's willingness to shift and the shift duration.

Challenges in the Electricity Market

The electricity market design in Europe is based on the so-called energy-only market; people only pay for electricity that is actually supplied. In Switzerland, electricity is sold on a uniform tariff, meaning that the price per kilowatt hour is the same, regardless of the time of consumption, or a day-and-night tariff, which is slightly lower during the night than during daytime. Since these tariffs barely reflect the current supply-and-demand situation on the electricity market, private households lack information about the effective electricity availability at any given time. Furthermore, the electricity market for private households in Switzerland is not liberalized. In this country, the energy supply is linked to the place of residence; thus, electricity tariffs can vary from one place to another (Eidgenössische Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK), 2021). Due to the expanding electrification and the growing share of new renewable energy sources (e.g., solar and wind power), flexibility is becoming increasingly important for the operation of a reliable energy system. A flexible energy system can maintain continuous service despite rapid and significant changes in energy supply and demand (Babatunde et al., 2020). To achieve system-level flexibility, the demand-side flexibility must be considered an integral component.

In most European countries, electricity consumption peaks at around 7:00 a.m., during lunchtime (around 12:00 noon), and around 5:00–10:00 p.m. (Torriti and Santiago, 2019). This consumption pattern is not necessarily aligned with the production pattern. For example, nuclear power plants generate electricity steadily, but solar and wind power are strongly weather dependent. Consequently, with a higher share of renewable energy, the generation of electricity becomes more volatile. Since the efficient storage of large amounts of energy remains very difficult, the two patterns must align in other ways (Schmietendorf et al., 2017; Wang et al., 2022). Switzerland is currently in a rather privileged position since hydropower accounts for 57% of its total electricity production. Over half of these are storage or pumped storage hydropower plants (Bundesamt für Energie [BFE, Swiss Federal Office of Energy], 2022). Nevertheless, providing electricity at peak times is often much more expensive for suppliers than doing so at off-peak hours (Torriti and Santiago, 2019) because additional power plants need to be activated (and therefore would have to be built) to provide a high amount of energy for a short period. This price difference between peak and off-peak hours is currently not reflected in the price charged to consumers. It is therefore not surprising that 49–69% of people are unaware of the peak hours of consumption (Zanocco et al., 2022).

The market is challenged with the increase in both electricity consumption (e.g., due to the charging of electric cars; Arias and Bae, 2017) and the use of power and heat pumps (Baeten et al., 2017), as well as the concern that demand could exceed supply in the future, especially at peak times (Andersen et al., 2017). Another challenge is the provision of the necessary grid capacity since overloading would lead to blackouts (Chakraborty et al., 2015). Of the total electricity exchanged between European countries, 10% flows through Swiss grids. Therefore, an increased electricity demand inland and from surrounding countries would result in an increased demand for grid capacity (Eidgenössische Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK), 2021). However, expanding the network would be a time-consuming and resource-intensive process that would probably be unable to keep up with the pace of other developments in the energy field. All these reasons trigger the need for flexible consumer profiles matching the supply variations.

Today's solutions, especially in Switzerland, are mainly supply-side responses; increasing electricity demands at peak hours are met by generating additional electricity, mainly from water of storage lakes, fossil fuels, or imported electricity from surrounding countries. Supply-side solutions often force producers to generate carbon-intensive and expensive electricity (Torriti and Santiago, 2019) and can put system reliability at risk. Shifting certain electricity-intensive activities from peak to off-peak hours could lead to a more sustainable, reliable, and efficient system, especially regarding renewable power plants. While many countries (e.g., France [EDF Particulier, 2022], Italy [Maggiore et al., 2013], and Norway [Hofmann and Lindberg, 2023]) have already introduced demand–response systems, Switzerland has not yet done so.

Demand–Response Systems and Pricing Policies

Demand–response systems involve technologies and strategies that enable consumers to adjust their electricity usage in response to supply and/or pricing information. When supply is regulated through price, the price increases when the demand exceeds the supply and decreases when the supply exceeds the demand. The aim of flexible prices is to steer consumer consumption towards scheduling at-home activities that optimize energy use and contribute to an efficient and flexible energy grid.

Various pricing policies incorporate the supply–demand principle to a certain extent. Examples include time-of-use tariffs (different tariffs for different times of the day — also called peak and off-peak pricing) and real-time pricing (prices change at regular intervals of one hour or a few minutes; for more details on pricing policies, see, e.g., Dutta and Mitra, 2017).

Pricing policies greatly differ among countries. In Great Britain, many suppliers offer a variety of options, such as time-of-use and fixed tariffs (British Gas, 2022). Consumers can therefore choose the tariff structure that fits them best in terms of price and flexibility. France provides a tariff option (EDF Particulier, 2022) that uses three colours to indicate the expected level of consumption on a specific day (low, medium or high). In Norway, most households have hourly changing prices of electricity (Hofmann and Lindberg, 2023). While most of the countries with commercially available, dynamic tariff options have made residential end users' participation optional, some countries (e.g., Italy) have made it mandatory (Maggiore et al., 2013).

Incorporating time-varying rates often involves equipping consumers with smart metres (Faruqui et al., 2010a, 2010b). These metres continuously measure real-time energy consumption and signals when usage exceeds the available supply, often conveyed through peak or price signals (Torriti, 2020). Stressing the importance of detailed feedback from smart metres, Abrahamse et al. (2005) advocate information breakdowns to the level of individual devices, rooms, and functions, empowering consumers to make informed decisions.

Past research has emphasized demand–response systems' potential to achieve a substantial peak reduction, ranging from 0 to 60% (e.g., Faruqui and Sergici, 2013; Kathan, 2009; Newsham & Bowker, 2010). However, Davis et al. (2013) assert that this peak reduction is often exaggerated; their meta-analysis reveals a more conservative reduction of approximately 6% through dynamic pricing when adjusted for risk-of-bias from inadequate experimental designs. Furthermore, the effectiveness of dynamic pricing can be optimized when combined with programmable smart devices that autonomously respond to price or peak signals (Davis et al., 2013; Faruqui and Palmer, 2012; Faruqui and Sergici, 2013; Faruqui et al., 2017, 2010a, 2010b). For instance, appliances such as dishwashers can be programmed to activate during periods of low electricity tariffs, while refrigerators can adjust their cooling levels during high-tariff intervals. Davis et al. (2013) demonstrated that this combined approach resulted in a significant peak reduction of around 14% when adjusted for bias, highlighting the potential for increased efficiency in peak demand management.

Various factors could be responsible for the variability observed in the reported effects. These include differences in peak to off-peak price ratios, variations in the duration of measurement periods (Faruqui and Sergici, 2013; Faruqui et al., 2017), and seasonal disparities (Öhrlund et al., 2019a, 2019b). Additionally, contextual distinctions, such as cultural differences, social norms, and habits, play a crucial role in understanding the diverse outcomes (Heiskanen et al., 2020).

Flexibility in Shifting the Uses of Different Devices

A large body of literature reports calculated load profiles (energy demand) based on available data from public reports and statistics (Dupont et al., 2014; Finn et al., 2013; Paatero and Lund, 2006). These models aim to realistically represent the load profiles of households or devices and to find out how the loads can be shifted to match the supply in an optimal way. Furthermore, modelling enables the estimation of the amounts of money and energy resources that can be saved and the volume of carbon dioxide (CO_2) emissions that can be reduced. However, such studies are often limited by the fact that they do not integrate into their models the characteristics of the individual devices per household, the households' willingness to adopt flexibility or the perceived effort to do so (Dupont et al., 2014). We consider it necessary to address these limitations; therefore, we aim to find out the extent of people's willingness to shift their electricity-intensive, at-home activities and how long they would shift their planned use of different devices.

In their field study, Azarova et al. (2020) found that people were willing to curtail their electricity use at home for 15 min per week (with or without receiving a certain benefit). Some of the curtailments were so huge that no electricity was used at all for the 15-min period. However, Azarova et al. did not measure which devices were switched off.

In previous studies, details on the participants' experiences in dealing with flexible pricing systems were revealed mostly through interviews. Eating, watching television (Powells et al., 2014), and other leisure activities (Öhrlund et al., 2019a, 2019b; Ozaki, 2018; Smale et al., 2017) were found to be the most commonly occurring but the least flexible in terms of shifting. Cleaning practices (e.g., laundry) had higher perceived flexibility (Powells et al., 2014). Stelmach et al. (2020) observed similar results from their survey. Using a binary scale (yes, no), they asked the participants whether they were willing to shift different activities away from the peak period (in their case, 3:00–9:00 p.m.). The participants' indicated willingness to shift was relatively low (20–30%) for watching television, cooking, using computers, using lights, electric cooling, and electric heating. In contrast, household chores appeared to be the most flexible (80–90%), including using the washing machine, the clothes dryer, and the dishwasher. Medium levels of the participants' willingness to shift (52–53%) their hours of showering or bathing were noted.

We agree with Stelmach et al. (2020), who mentioned in their study's limitations that the willingness to shift was not rigidly binary but had different levels. Accordingly, in this study, we used a more fine-grained assessment to examine people's willingness to shift their electricity-consuming activities to off-peak hours. Moreover, we believe that it is crucial to assess the shift duration as the period defined in a shift, such as when a delayed peak or a rebound peak occurs. We further decided to include only the devices that consume energy directly when used. In contrast to other authors (e.g., Stelmach et al., 2020), we excluded devices operating from a reservoir, such as those used for showering and bathing, because delaying these activities would not directly influence the current energy consumption. We also refrained from including heating and cooling as activities in the survey. In Switzerland, over 90% of heating systems run independently (powered by oil, gas or wood) from the electricity grid (Bundesamt für Statistik [BFS, Swiss Federal Office of Statistics], 2022), and cooling devices, such as air conditioners, are rarely found in the country. Furthermore, previous studies defined a clear peak window. For example, a 6-h peak window was associated with a 30% price increase compared to off-peak times (Stelmach et al., 2020). However, in the future, much more volatile pricing systems will most likely come into play, and the peak to off-peak price ratio may be much more pronounced than 30%. In this study, we did not predefine a peak window but assessed the maximum acceptable shift duration for the use of each device. Additionally, we tested if individuals who would adapt their consumption behaviour at an already lower electricity price increase (assessed by an item asking how high the price should be for them to start adapting) would be more willing to shift their use of appliances and electronic devices for a longer duration.

Drivers of and Barriers to Shifting Behaviours

It is important to gain more knowledge about the flexibility of consumers because this is one factor that can contribute to a secure and stable energy supply. Hence, we searched the relevant literature to identify factors related to constructs associated with consumers' flexibility, including general energy-saving behaviours. We aim to determine whether these factors can also explain consumers' willingness to shift and the shift duration. In the following subsections, we briefly discuss each of the identified factors.

Lifestyle Compatibility

Lifestyle compatibility indicates whether people feel able to integrate changes into their everyday lives. People's behaviour often evolves by trading off various factors since they cannot always do what they want, given that many circumstances determine what they can or need to do (Baron, 2023). People's lifestyles, such as working long hours or parenting, seem to have a significant impact on their acceptance of dynamic pricing systems (Faruqui et al., 2010a, 2010b; Nicholls and Strengers, 2015; Torriti, 2015) since such living conditions strongly influence their possibilities to freely shape their everyday lives. If people perceive behavioural changes involving energy consumption as too troublesome in daily practice, they become unwilling to subscribe to a demand–response programme (Yang et al., 2018).

Based on these findings, we expect consumers to be more willing to shift their electricity-intensive activities, the more they perceive their lifestyles to be compatible with a dynamic pricing system.

Perceived Effort

A change is more likely to be implemented if it is perceived as low in cost or effort (Van Raaij and Verhallen, 1983) or if the perceived effort fits a person's motivational level (Dreijerink et al., 2022). The perceived effort is considered an important factor that negatively influences behavioural adaptation (Van Raaij and Verhallen, 1983). Effort is a complex construct. It includes the temporal and physical efforts to implement actions (lowering the thermostat, etc.), the mental effort to integrate new behavioural patterns into a person's daily routine, and the perceived effort of coping with the change itself, such as spending one's evenings in a slightly colder living room (Van Raaij and Verhallen, 1983). Moreover, people tend to show eco-friendly behaviours (e.g., electricity-saving or shifting behaviours) in areas where they expect the least effort in implementing such changes (Sütterlin et al., 2011). For example, many people recycle but do not forego flying on holidays (Kollmuss and Agyeman, 2002).

Based on these previous findings, we expect a negative influence of perceived effort on the willingness to shift electricity-consuming activities and on the shift duration. Furthermore, we predict the level of perceived effort to differ among electricity-consuming, at-home activities.

Motivational Factors

Several motivational factors were found to have a positive influence on consumers' willingness to shift their hours of performing certain at-home activities (Albadi and El-Saadany, 2008; Lashmar et al., 2022; Nilsson et al., 2018; Parrish et al., 2020; Sloot et al., 2022; Udalov et al., 2017). To increase their motivation to participate in demand–response programmes, consumers are usually offered different benefits, such as financial rewards (Albadi and El-Saadany, 2008; Lashmar et al., 2022; Nilsson et al., 2018). Other factors that were shown to increase consumers' openness to shift were their care for environmental benefits, their motivation to reduce the likelihood of a blackout

(Srivastava et al., 2018), and their motivation to contribute to a stable grid and thus the security of supply (Annala et al., 2014; Lashmar et al., 2022; Nilsson et al., 2018).

Positive effects on consumers' willingness to adjust their electricity consumption towards a more efficient and cost-effective system were also observed in relation to bill reduction (Gamma et al., 2021), while mixed effects for bonus–malus systems were found (Mahmoodi et al., 2021). The motivation to reduce electricity consumption for environmental reasons was mainly reported by people who were also environmentally conscious in other areas of their lives (Sloot et al., 2022). Segmentation studies revealed that below 50% of consumers put environmental protection above economic motivation (e.g., Mahmoodi et al., 2021).

We assume that motivational factors play a significant role in influencing consumers' willingness to shift electricity-intensive activities away from peak hours, as well as the duration of that shift. Therefore, we aim to shed more light on different motivational factors, such as the abilities to reduce electricity bills, contribute to grid stability, decrease blackout risks, and contribute to more environment-friendly energy production.

Attitudes

We anticipate certain attitudes to have impacts on consumers' willingness to shift and on the shift duration of electricity consumption. These attitudes might encompass individuals' interest in and stance towards technology (Sloot et al., 2022), as well as their responses to certain policy changes, such as electricity market liberalization. Market liberalization is not a strict requirement for a dynamic electricity pricing system, but both systems stipulate that consumers have a choice and can influence the outcomes (e.g., the amounts of their electricity bills) with their behaviour.

We therefore expect these attributes to serve as positive predictors of users' willingness to shift electricity-consuming activities and of the shift duration.

Demographics

Recent studies investigating demographic variables showed being older and female as positively related to energy-saving behaviour (Umit et al., 2019). There were mixed results regarding income. Some studies found no influence of income (e.g., Umit et al., 2019) on energy efficiency and curtailment behaviour; others noted that a lower income led to higher price elasticity (e.g., Alberini et al., 2011). Since there is no clarity in the literature regarding sociodemographic variables, we aim to investigate the effects of gender, age, and income on the willingness to shift and the shift duration.

In summary, with a future-oriented perspective that anticipates increased volatility in electricity production due to the growing share of new renewable energies, peak windows are assumed to change significantly. Therefore, we consider it important to explore whether and how much the use of different appliances and electronic devices would be shifted, regardless of a clearly defined time window. Furthermore, existing research has not captured the extent of the shift but whether something would be shifted or not. By assessing people's willingness, perceived efforts, and duration, we can gain deeper insights into their shifting behaviours and draw conclusions about how different individuals would handle different devices under the assumption of high electricity prices.

Study Aims and Hypotheses

In this study, we aim to explore individuals' willingness to shift different planned activities and the duration for which they would shift their planned use of certain devices, assuming the increasing electricity price at that moment. We investigate whether and how these shifting behaviours are influenced by personal characteristics, such as lifestyle compatibility, individuals' perceived effort, and their willingness to engage in energy-saving behaviour. We address the following questions:

- Which planned activities are preferably shifted?
- What is the perceived level of effort in shifting planned activities?
- For how long would participants shift their use of certain devices?
- What factors can explain the variance in the acceptance of these shifting behaviours?

We hypothesize that consumers' willingness to shift differs, depending on the specific type of at-home activity. Based on previous research (e.g., Gamma et al., 2021; Lashmar et al., 2022; Mahmoodi et al., 2021; Sloot et al., 2022; Srivastava et al., 2018), we expect the use of household cleaning devices to be associated with a higher willingness to shift, a longer shift duration, and less perceived effort in comparison to the use of devices for leisure activities. Furthermore, we assume that different factors, such as consumers' environmental attitudes or perceived compatibility of their lifestyles with a change in their electricity-consumption activities, are associated with their willingness to shift and the shift duration.

This understanding of consumers' willingness to shift can help policymakers, public authorities, and service providers implement intervention strategies, develop appropriate tools, and apply flexible pricing systems that consumers can use effectively.

Methods

Sample

The participants were recruited from an internet panel provided by a commercial sampling service provider (Bilendi Schweiz AG). In total, 1,122 participants completed our online survey, conducted in July 2022. Quota samples were used with the variables of gender (50% men, 50% women) and age (32%: 20–35 years, 35%: 36–49 years, 33%: 50–69 years). We excluded participants whose total duration of survey completion was less than half of the median time (1/2* $Med_{time} = 8.46$ min; $n = 160$), indicating that they did not answer the questions seriously.

The final sample ($N = 962$) comprised 460 females (48%) and 495 males (51%); one person did not indicate any gender, and six people chose "other." The participants had a mean age of 44 years ($SD = 4$ years). Their educational backgrounds fairly represented the Swiss average[1]; 33% earned a university degree, 18% attended higher vocational training,

[1] Demographics of Swiss population: $M_{age} = 42.8$, 50.31% females, 49.69 males; (Bundesamt für Statistik [BFS, Swiss Federal Office of Statistics], 2024). 29.7% holding a university degree, 15% attended higher vocational training, 6.8% attended high school, 34.5% attended vocational training, and 13.9% completed lower secondary or primary school (Bundesamt für Statistik [BFS, Swiss Federal Office of Statistics], 2022).

Table 1 Results of multiple linear regression analyses predicting willingness to shift

Predictor	*B*	*β*	*SE*	*CI 99% for β*		*t*	*p*
				LL	*UL*		
(Intercept)	2.07	0.00	0.38	−0.07	0.07	0.00	1.00
Gender	0.02	0.01	0.06	−0.06	0.08	0.27	0.78
Age	0.00	0.00	0.00	−0.07	0.08	0.15	0.88
Education	0.03	0.05	0.02	−0.02	0.13	1.88	0.06
Income	−0.01	−0.02	0.02	−0.09	0.06	−0.55	0.58
Liberalization	**0.06**	**0.07**	**0.02**	**0.00**	**0.14**	**2.69**	**< 0.01**
Energy-saving behaviour	0.12	0.08	0.05	0.00	0.16	2.52	0.01
Pro-environmental identity	0.05	0.05	0.03	−0.04	0.13	1.46	0.14
Lifestyle compatibility	**0.23**	**0.23**	**0.03**	**0.15**	**0.31**	**7.85**	**< 0.001**
Perceived effort to shift	**−0.36**	**−0.33**	**0.03**	**−0.41**	**−0.26**	**−11.52**	**< 0.001**
Motivation: grid stability	**0.22**	**0.15**	**0.05**	**0.06**	**0.24**	**4.23**	**< 0.001**
Motivation: CO_2 reduction	0.02	0.02	0.05	−0.07	0.11	0.52	0.61
Motivation: bill reduction	−0.03	−0.02	0.05	−0.10	0.05	−0.81	0.42
Price insensitivity to change	**0.01**	**0.08**	**0.00**	**0.01**	**0.15**	**3.03**	**< 0.01**
Attitude towards climate-friendly energy technology	0.06	0.05	0.03	−0.02	0.13	1.85	0.06
Perceived likelihood of blackout	0.00	0.00	0.00	−0.06	0.07	0.18	0.86

N = 928. Thirty-four observations were deleted due to missing data. Significant predictors (***p*** < 0.01) are printed in bold font. $R^2 = 0.36$

CI confidence interval, *LL* lower limit, *UL* upper limit

10% attended high school, 34% attended vocational training, and 4% completed lower secondary or primary school.

Study Design and Procedure

Prior to the data collection, we obtained ethical approval from our university's ethics committee (EK 2022-N-127). The participants were initially informed about the study's duration and topic, and their anonymity was assured. After they agreed to participate, their demographic information (age, gender, educational level, political orientation, income, lifestyle compatibility, and income satisfaction) was assessed.

Questionnaire

In the survey, the participants read an introductory text that provided information about flexible pricing systems and their relations to electricity supply and demand (see Appendix A). The questionnaire comprised 22 variables, of which 15 were relevant for the subsequent analysis. Detailed item wording and descriptive statistics can be found in Appendix B, Table B1.

Data Analyses

We conducted statistical analyses using the open-source software R (R Core Team, 2022). Descriptive analyses were used to analyse the distribution of our sample, handle outliers, and check the resemblance between our sample and the general Swiss population. To verify the validity and reliability of the variable measurements, we first performed factor analyses and reliability analyses. Cronbach's alpha coefficients and item total correlation (ITC) were used to indicate the reliability.

Multiple linear regression models were calculated to explore how different factors (e.g., sociodemographic characteristics, energy-saving attitudes) influenced the shifting behaviour. Separate models were calculated for the dependent variables *willingness to shift* and *shift duration*. A significance level of $p < 0.01$ was applied.

Results

Willingness to Shift

Which Planned Activities Are Preferably Shifted?

We examined the participants' willingness to shift five common at-home activities (cooking/baking, doing the laundry, charging devices, watching movies, and eating). A factor analysis (maximum-likelihood method) revealed one factor influencing the willingness to shift (for more details, see Appendix B, Table B3). A within-subject ANOVA was significant ($F(3.30, 2758.03) = 148.65$, $p < 0.001$), and post hoc tests (pairwise comparisons, Benjamini and Hochberg corrected) revealed significant differences in the participants' willingness to shift across these activities (see Fig. 1).

Which Factors Can Explain the Variance in the Willingness to Shift?

We conducted a multiple linear regression analysis (Table 1) with the mean score of the *willingness to shift the five at-home activities* as the dependent variable and the selected potential independent factors influencing the willingness to shift. The model ($F(15, 911) = 33.69$, $p < 0.001$) explained 36% of the variance. The perceived effort turned out to be the strongest predictor, with an inverse impact on the willingness to shift. A higher perceived compatibility with the participants' lifestyles, the motivation to contribute to grid stability, and a greater openness to a liberalized electricity market were associated with a higher willingness to shift. The participants with higher price insensitivity were also more willing to shift their activities. Sociodemographic factors (gender, age, and education) and environmental variables (pro-environmental identity, reported energy-saving behaviour, and motivation to reduce CO_2 emission) were not significant at the $p < 0.01$ level.

Perceived Effort to Shift

What Is the Perceived Level of Effort in Shifting Planned Activities?

We examined the participants' perceived effort to shift the five at-home activities, as depicted in Fig. 2. The factor analysis (maximum-likelihood method with varimax rotation)

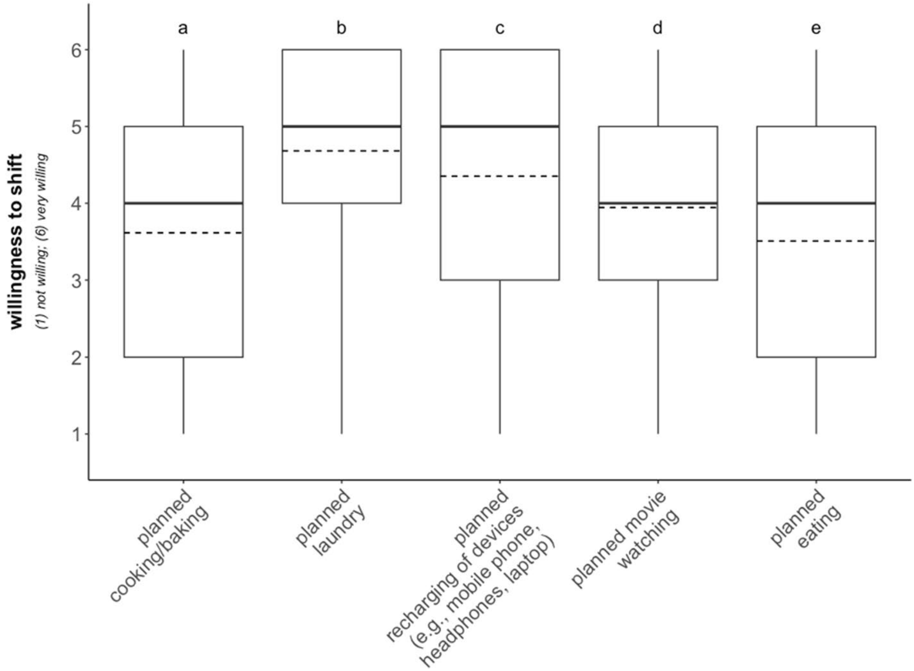

Fig. 1 Boxplots illustrate participants' willingness to shift the five activities in times of high electricity prices. $N = 836$. The participants who chose the option "I never do this activity" were excluded from the analysis. The thick horizontal line in each plot marks the median; the dashed line marks the mean. The box ranges from the 25th to the 75th percentile and therefore contains 50% of the data points. Different superscripts indicate statistically significant mean differences

revealed one factor underlying the perceived effort to shift (see Appendix B, Table B4). A within-subject ANOVA with the dependent variable *perceived effort* showed a significant main effect ($F(3.52, 2986.83) = 171.95$, $p < 0.001$), and post hoc tests (pairwise comparison, Benjamini and Hochberg corrected) indicating differences in effort scores between all activities, except charging devices and watching movies.

Shift Duration of Device Use

For how long would the participants shift their use of appliances and electronic devices?

To assess the maximum shift duration of planned device use, the participants responded on a scale, ranging from "not willing at all" to "up to 24 h" (see Fig. 3). A factor analysis identified two factors (see Appendix B, Table B5): flexible devices ($\alpha = 0.85$, ITC > 0.70) with long shift durations and inflexible devices ($\alpha = 0.72$, ITC > 0.50) with shorter durations.[2]

[2] A pairwise *t*-test confirmed that flexible devices ($M = 5.51$, $SD = 1.99$) were associated with significantly longer shift durations compared to inflexible devices ($M = 3.71$, $SD = 1.64$; $t = -21.95$, $p < .001$).

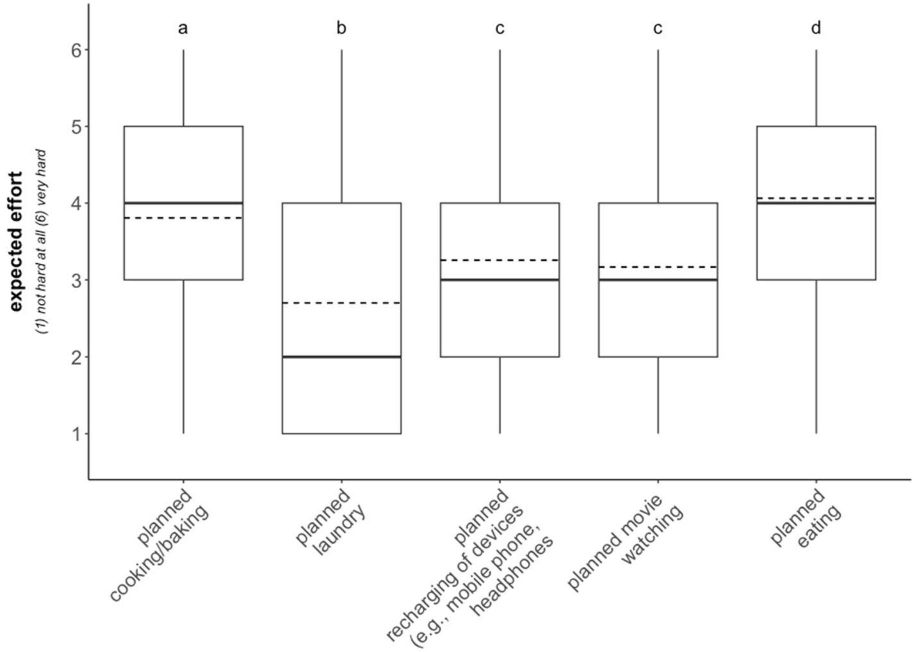

Fig. 2 Boxplots of perceived effort to shift activities in times of high electricity prices. $N = 849$. The participants who chose the option "I do not do this activity" were excluded from the analysis. The thick horizontal line in each plot marks the median; the dashed line marks the mean. The box ranges from the 25th to the 75th percentile and therefore contains 50% of the data points. Different superscripts indicate statistically significant mean differences

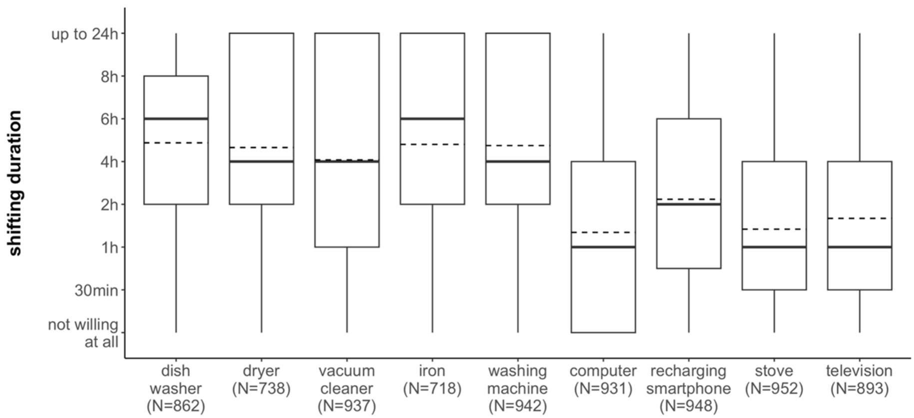

Fig. 3 Boxplots of indicated shift duration of device use in times of high electricity prices. The participants who chose the option "I do not use this device" were excluded from the analysis. Each number in brackets indicates how many participants answered the item. The thick horizontal line in each plot marks the median, whereas the dashed horizontal line marks the mean. The box ranges from the 25th to the 75th percentile and therefore contains 50% of the data points

Table 2 Results of multiple linear regression analyses predicting the shift duration of using flexible devices

Predictor	*B*	*β*	*SE*	*CI 99% for β*		*t*	*p*
				LL	*UL*		
(Intercept)	1.60	0.00	0.67	−0.07	0.08	2.30	0.02
Gender	0.08	0.02	0.11	−0.06	0.10	0.68	0.48
Age	0.01	0.04	0.00	−0.04	0.12	1.42	0.19
Education	0.05	0.04	0.04	−0.04	0.12	1.43	0.19
Income	0.05	0.04	0.04	−0.04	0.12	1.43	0.16
Liberalization	0.01	0.01	0.04	−0.07	0.09	0.21	0.76
Energy-saving behaviour	**0.36**	**0.14**	**0.09**	**0.05**	**0.23**	**4.26**	**<0.001**
Pro-environmental identity	−0.02	−0.01	0.06	−0.10	0.08	−0.37	0.72
Lifestyle compatibility	**0.19**	**0.12**	**0.05**	**0.04**	**0.20**	**3.83**	**<0.001**
Perceived effort to shift	**−0.45**	**−0.25**	**0.06**	**−0.33**	**−0.17**	**−7.96**	**<0.001**
Motivation: grid stability	0.18	0.07	0.09	−0.02	0.17	1.92	0.05
Motivation: CO_2 reduction	0.01	0.01	0.08	−0.09	0.10	0.30	0.86
Motivation: bill reduction	**0.42**	**0.17**	**0.08**	**0.09**	**0.26**	**5.17**	**<0.001**
Price insensitivity to change	−0.01	−0.06	0.01	−0.13	0.02	−1.96	0.06
Attitude towards climate-friendly energy technology	0.04	0.02	0.05	−0.06	0.10	0.65	0.46
Perceived likelihood of blackout	0.00	0.06	0.00	−0.02	0.13	2.06	0.05

$N = 929$. In total, 33 observations were deleted due to missing data. Significant predictors ($p < 0.01$) are printed in bold font. $R^2 = 0.26$

CI confidence interval, *LL* lower limit, *UL* upper limit

Which Factors Explain the Shift Duration of Using Flexible Devices?

We conducted multiple linear regression analyses (Table 2) with the dependent variable *shifting duration for flexible devices*, using the same predictors as those in the model for the willingness to shift. The model ($F(15, 924) = 23.38$, $p < 0.001$) explained 26% of the variance. Perceived effort was the strongest predictor, indicating that higher effort was associated with shorter shift durations. The participants who were motivated to reduce their electricity bills indicated their willingness to opt for longer shift durations. The choice for longer shift durations was also noted among the participants who were more engaged in energy-saving behaviour and indicated a higher perceived compatibility with their lifestyles. Sociodemographic variables (gender, age, and education), pro-environmental identity, motivation to reduce CO_2 emission, and perceived likelihood of a blackout were unrelated to shift duration at the $p < .01$ level.

Which Factors Explain the Shift Duration of Using Inflexible Devices?

Finally, we conducted multiple linear regression analyses with the dependent variable *shift duration of using inflexible devices* (Table 3) and the same predictors as those used in previous models. The model ($F(15, 913) = 25.77$, $p < 0.001$) explained 30% of the variance. Perceived effort remained a key predictor that had a negative influence on the shift duration of using

Table 3 Results of multiple linear regression analyses predicting the shift duration of using inflexible devices

Predictor	*B*	*β*	*SE*	*CI 99% for β*		*t*	*p*
				LL	*UL*		
(Intercept)	3.76	0.00	0.03	−0.07	0.07	−0.02	0.99
Gender	−0.12	−0.04	0.03	−0.11	0.04	−1.28	0.20
Age	0.00	−0.02	0.03	−0.09	0.06	−0.58	0.56
Education	0.02	0.02	0.03	−0.06	0.10	0.68	0.50
Income	**−0.10**	**−0.09**	**0.03**	**−0.17**	**−0.02**	**−3.15**	**<0.01**
Liberalization	0.02	0.02	0.03	−0.06	0.09	0.61	0.54
Energy-saving behaviour	0.02	0.01	0.03	−0.07	0.10	0.37	0.72
Pro-environmental identity	**0.16**	**0.10**	**0.03**	**0.01**	**0.19**	**2.92**	**<0.01**
Lifestyle compatibility	**0.25**	**0.19**	**0.03**	**0.11**	**0.27**	**6.24**	**<0.001**
Perceived effort to shift	**−0.48**	**−0.33**	**0.03**	**−0.41**	**−0.25**	**−10.84**	**<0.001**
Motivation: grid stability	**0.20**	**0.10**	**0.04**	**0.00**	**0.20**	**2.68**	**<0.01**
Motivation: CO_2 reduction	0.07	0.04	0.04	−0.06	0.13	0.99	0.32
Motivation: bill reduction	0.01	0.00	0.03	−0.08	0.09	0.16	0.88
Price insensitivity to change	**0.01**	**0.07**	**0.03**	**0.00**	**0.15**	**2.50**	**<0.01**
Attitude towards climate-friendly energy technology	−0.04	−0.03	0.03	−0.11	0.05	−0.89	0.37
Perceived likelihood of blackout	0.00	0.07	0.03	0.00	0.14	2.42	0.02

$N=930$. In total, 32 observations were deleted due to missing data. Significant predictors ($p<0.01$) are printed in bold font. $R^2=0.30$

CI confidence interval, *LL* lower limit, *UL* upper limit

inflexible devices. Conversely, lifestyle compatibility had a positive effect on the shift duration. A stronger pro-environmental identity, price insensitivity, and the motivation to contribute to grid stability were positive predictors. Among the sociodemographic variables, only income was negatively related to shift duration. The attitude towards climate-friendly technology, blackout likelihood, and the motivation to reduce CO_2 emission were unrelated to the dependent variable at the $p<.01$ level.

Discussion

In this research, we investigated individuals' willingness to shift different at-home activities involving electricity consumption and the shift duration of using different devices. We also examined how different factors influenced the degree of individuals' willingness to shift certain activities and the shift duration of device use.

Our findings show that most people are willing to shift their planned activities, and they indicate a shift duration above zero for the different devices. Different constructs, such as perceived effort and lifestyle compatibility, as well as ecological, financial, and motivational variables, help explain a person's willingness to shift and characterize the shift duration. Our study's results further provide evidence that the willingness to shift and the shift duration depend on the type of activity or device, respectively. The accepted duration of shifting the use of devices related to cleaning (e.g., dishwasher) is much longer than that of devices related to free time (e.g., television) or work (e.g., computer). Shifting laundry tops the list, with the highest willingness, the longest shift duration, and the lowest perceived effort. In their qualitative research, Powells et al. (2014) reported similar results. Their interviewees indicated that cleaning activities were more "improvisational," whereas other activities, such as cooking, were more scheduled according to their work and school hours (and probably hunger feelings).

Our study's participants reported the lowest willingness and the highest perceived effort to shift their cooking and eating activities. Planned eating does not necessarily include the usage of power, whereas cooking almost always does. Nonetheless, since the two activities often go hand in hand, both are unsurprisingly rated similarly low in the willingness to shift and the shift duration. This indicates that the participants do not want to be stopped from cooking when it is planned and therefore do not think of workaround strategies, such as eating something that does not require cooking.

Our results show that the willingness to shift, the shift duration of using flexible devices (e.g., dishwasher, dryer), and the shift duration of using inflexible devices (e.g., charging a smartphone, watching movies) are not shaped by the same factors. Two factors — perceived effort and lifestyle compatibility — influence all three variables in the same way, but apart from this, there are many differences.

Lifestyle Compatibility

Similar to previous research findings (Faruqui et al., 2010a, 2010b; Institut für Energie- und Umweltforschung [IFEU; Institute for Energy and Environmental Research], 2021), our data show that people's lifestyles largely affect their electricity usage behaviour. Individuals who perceive that behavioural changes can be easily integrated into their everyday lives indicate a higher willingness to shift activities and a longer shift duration. Interestingly, lifestyle compatibility seems highly subjective due to its low correlation with the actual hours spent at home (see Appendix B, Table B2). The questions on lifestyle compatibility leave room for interpretation, focusing solely on perceived compatibility without delving into the underlying reasons. Further exploration of this issue is needed since it could yield insights into potential strategies (e.g., home office, flexible work hours) to enhance people's subjective compatibility in shifting planned electricity-related activities. The positive associations between willingness and compatibility and between duration and compatibility suggest that the participants may have already considered their lifestyle compatibility in their decisions about their willingness to shift and the shift duration when responding to the questionnaire. Interestingly, lifestyle compatibility is negatively correlated with perceived effort in shifting, indicating that individuals with greater lifestyle compatibility perceive behavioural adaptations as less effortful.

Perceived Effort

According to the results, the level of the perceived effort plays a huge role in behavioural changes (Kollmuss and Agyeman, 2002; Van Raaij and Verhallen, 1983). Our data reveal that perceived effort negatively influences the degree of the willingness to shift and the shift duration. In the survey, the participants were asked to take into account all facets of perceived effort (i.e., temporal, financial, physical, and mental) since we considered it a holistic construct.

However, in future research, it would be worthwhile to find out which specific considerations would lead to a decrease in perceived effort. For example, time and money could be regulated externally (e.g., via remote control). Interestingly, our data show that people who identify more strongly with the environment generally report a lower perceived effort in shifting their device use. Future research should investigate which aspects of effort the participants precisely have in mind when asked about their effort estimation. It could be promising to consider psychological aspects of perceived effort — for instance, motivated reasoning or other cognitive biases — because processes such as selective attention, that is, the preferential acceptance and retrieval of information that are consistent with an individual's attitude, might be crucial in arriving at a conclusion about the perceived effort to engage in an activity.

Environmental Attitudes

Willingness to shift and shift duration of using flexible devices are positively influenced by energy-saving behaviour (Markle, 2013) but not by pro-environmental identity (Brick and Lai, 2018). The energy-saving behaviour scale focuses on individuals' usage of electricity-powered devices, which is closely related to their shifting behaviour, and both the energy-saving and the shifting scales are behaviour-based measures. Therefore, significant relations between these scales are not surprising. Additionally, energy-saving behaviour is not only ecologically relevant but also tied to economic considerations since a lot of energy-saving behaviours result in cost savings. This contrasts with pro-environmental identity, which is less connected to economic advantages.

We assume that people with a high pro-environmental identity show a deeper inner conviction to look after the environment and therefore demonstrate a longer shift duration of using inflexible devices. Interestingly, the motivation to reduce CO_2 emission predicts neither the willingness to shift nor the shift duration, but a correlation analysis reveals that the motivation to reduce CO_2 emission is positively related to the willingness to shift and the shift duration. These findings suggest that the effect of the motivation to reduce CO_2 emission on shifting behaviour is mediated by one or more variables related to the willingness to shift or the shift duration, such as pro-environmental identity. As each of our motivational variables is a one-item measure, the mediational effect cannot be tested reliably. Accordingly, we recommend investigating the influence of the motivational aspects in more detail in future research.

Economic Attitudes

We investigated the effects of different economic variables. The first was the price insensitivity to change (which measures the electricity price at which people would initiate their shifting behaviour); the higher the indicated price, the more price insensitive people are assumed to be. The second was how motivated people would be to reduce their electricity bills through shifting behaviour, and finally, the influence of the household income on willingness to shift and shift duration.

Unexpectedly, individuals with a higher price insensitivity also indicate a higher willingness to shift their electricity consumption in general. We speculate that this result is due to the structure of the questionnaire. In our instructions, we asked the participants to imagine how they would behave if the current price of electricity was high. In the item on price sensitivity, the participants had to indicate at which concrete price (0–5 CHF) they would start changing their behaviour.

Quite possibly, the participants kept this price indication in mind. A previous study also showed that higher price ratios led to people's higher willingness to change their behaviour (Heberlein and Warriner, 1983). Since we also indicated the current price of electricity in Switzerland (approximately 0.22 CHF/kWh) in the question about price sensitivity, the participants might have created their own ratios, and those with higher ratios then indicated a higher willingness.

Consistent with the results of previous studies (e.g., Gamma et al., 2021), our findings show that financial rewards, such as the possibility of reducing one's electricity bill, are positively related to curtailing electricity use, or in our case, shifting the duration of using flexible devices. Shifting the duration of using inflexible devices is in turn influenced by income — the higher the income, the shorter the duration. Previous studies regarding the influence of income noted contradictory findings. While some authors (Umit et al., 2019) found no effect of income on energy efficiency and curtailment behaviours, others (Alberini et al., 2011) observed a clear relation in the same direction as we did. We assume that people weigh their perceived effort against the saving potential. This saving potential may be perceived as greater for people with lower incomes than for those with higher incomes and therefore leads to a lower perceived effort. This assumption is further supported by the negative correlation between income and motivation by bill reduction (see Appendix B, Table B2), showing that people with lower incomes are more motivated to shift their activities when they can reduce their electricity bills. However, the regression analysis shows that the reduction of the electricity bill has no direct influence on the shift duration of using inflexible devices.

Supply Security

The shift duration of using inflexible devices and the willingness to shift at-home activities are higher for people who indicate a higher motivation to contribute to the stability of the electricity grid by means of their shifting behaviour. Previous studies also revealed that contributing to supply security could have a motivational impact on participation in demand–response programmes (Annala et al., 2014; Lashmar et al., 2022; Nilsson et al., 2018). Interestingly, the motivation to contribute to a stable grid and the perceived likelihood of a blackout show a very small correlation although both variables fall under the category of supply security. The lack of understanding about the causes of blackouts or the importance of grid stability may lead to this weak correlation.

Liberalization

We find that a pro-free-market attitude is positively linked to the shift duration of using flexible devices. Such an attitude is accompanied by the belief that free and therefore competitive markets lead to the highest efficiency in resource allocation. As shifting behaviour is also meant to increase electricity distribution efficiency, the link between shifting behaviour and a market liberalization attitude is not surprising. Furthermore, acting in a liberal market means having a choice and therefore being able to influence a certain outcome, such as the amount of the next electricity bill. These attitudes also align with shifting behaviour; when dynamic prices are offered, not only can people choose among tariff systems, but they can also directly act on the different tariffs by planning and shifting their electricity consumption. There is an ongoing debate about the question of which factor is more crucial for electricity peaks — people's characteristics or social practices (Powells et al., 2014). Based on our results, we assume that it involves a combination of the two factors. We do find influences of characteristics, such as motivational factors, ecological and economic attitudes, and income. However, we also observe a strong relation between the perceived compatibility of one's lifestyle and shifting behaviour, which, of course, may be shaped by external factors, such as work hours, as well as by habits and social practices. Future research should delve deeper into a quantitative analysis of which social practices influence shifting behaviour and how people can be motivated to adapt their habits accordingly.

Limitations and Implications for Further Research

In our survey, we worked with a hypothetical scenario that asked the participants to imagine how they would deal with their electricity-consuming devices in high electricity price periods. Hypothetical questions usually come with an intention–behaviour gap, so individuals might react differently in real life (Sheeran and Webb, 2016). Future research with actual user data on the device level could attempt to close the intention–behaviour gap by providing more practical insights into people's flexibility in response to actual price changes as opposed to the hypothetical approach taken in our analysis.

Furthermore, we did not specify any concrete peak windows but asked how people would react if the price was currently high. Previous studies sometimes chose rather long peak times (Stelmach et al., 2020) or very short ones (Azarova et al., 2020). However, since we wanted to measure the longest duration within which people were willing to shift a planned activity, we could not give a concrete indication about the durations of the peak windows. It is assumed that with the increasing share of new renewable energy sources, our dynamic price systems could become highly volatile; therefore, the peaks would considerably vary each day as well. Future research could investigate different durations of peaks and perform field tests on which devices would be willingly switched off and how an app could be designed to save enough electricity at peak times through shifting behaviour. Such field tests could also examine the rebound effect (Azarova et al., 2020). In their field study, Azarova et al. (2020) found that after the 15-min time window during which the participants were supposed to limit their electricity usage, their consumption instead increased disproportionately. Figuring out what devices would lead to this rebound and if the chosen time window would influence the intensity of the rebound peak would contribute to a better understanding of people's shifting behaviour. Furthermore, it could be worthwhile to discover what factors would lead to the resumption of the shifted activity immediately after the expiry of the peak-time window. This knowledge could also help motivate people to extend the activity that they performed during the high-price window.

Our study included questions about a limited number of activities and devices requiring electricity. Many more electricity-consuming activities and devices should be analysed in future research. We also recommend testing the effects of further variables, such as knowledge, since in previous research, the consumers' knowledge about volatile prices was found to be crucial for their acceptance (Yang et al., 2018).

Our three motivational scales are each based on a single item. Statistical analyses and relations based on single items might be underestimated due to the greater error variance. We therefore might have failed to find significant connections in our regression analyses (for more insights, see Allen et al., 2022). As stated above, we encourage researchers to investigate the motivation scales more thoroughly in future studies.

It is worth noting that our results can be generalized only to a limited extent due to significant variations in energy supply across countries and the energy field's susceptibility to rapid changes driven by technological advancements and political shifts.

Conclusions

Flexible pricing systems aim to use resources more efficiently by reflecting the supply-and-demand situation, thereby considering the characteristics of different forms of energy production. With this paper, we aim to go beyond the consumers' mere acceptance of flexible pricing systems by investigating their willingness to shift different at-home activities under the assumption of a high electricity price.

Our study suggests that people's willingness to shift and the shift duration of using a device depend on the type of activity. For example, people are highly willing to shift doing their planned laundry for several hours but prefer to cook and eat according to schedule. The degree of willingness and the duration further depend on the perceived effort that a person associates with the shift. Activities associated with more effort are related to a lower willingness to shift and a shorter shift duration. Our findings show that the perceived compatibility between shifting activities and a person's daily planning or lifestyle plays a major role in one's behaviour modification intention. People who perceive themselves as more flexible in their daily lives are more willing to shift their planned activities and would do so for longer periods of time. By breaking down observed impacts into device categories, we could gain a better understanding of how households intend to engage with flexible pricing systems.

Policy Implications

The following policy implications can be drawn according to the results and discussions. Nations adhering to rather inflexible electricity tariff structures (such as Switzerland) should consider transitioning to flexible options, allowing consumers to actively engage in demand-response systems, thereby aligning electricity consumption with their lifestyles and budgets. Furthermore, we recommend implementing a variety of pricing schemes that address different consumer priorities, including environmental consciousness (Mahmoodi et al., 2021; Sloot et al., 2022), financial incentives (e.g., Gamma et al., 2021), and a need for network security (Annala et al., 2014; Lashmar et al., 2022; Nilsson et al., 2018). To provide effective feedback on supply–demand dynamics, we recommend systems that provide personalized feedback at the device level (Abrahamse et al., 2005), focusing on activities that require minimal effort to shift, such as adjusting laundry schedules instead of planned leisure activities.

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Data Availability The dataset of the current study is available upon request.

Declarations

Conflict of Interest The authors declare no competing interests.

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