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# Impact of monetary incentives on the adoption of direct load control electricity tariffs by residential consumers

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**Abstract**

To overcome the inherent clash between the ever-increasing push for electrification in the transportation and heating sectors, and the intermittent nature of renewable energy sources, demand response solutions such as direct load control (DLC) tariffs are receiving growing attention from researchers and policymakers. The present study aims to investigate the impact of two measures (i.e. a video intervention and an upfront subsidy) in increasing the acceptance rates of an existing DLC tariff targeted at electric vehicle charging stations and heat pumps in Switzerland. To achieve this, we combine two randomized-controlled trials: (1) a stated-choice contingent valuation on electric vehicle owners to confirm the validity of the upfront susbidy, and (2) a revealed-preference field experiment on an existing DLC tariff proposed to the clients of a local distribution system operator. Results suggest that both measures of video and monetary intervention increase contact and subscription rates to the proposed DLC tariff, although the monetary intervention appears to be more convincing to consumers. Further, we use these results in combination with a bottom-up electricity market model to simulate the consequences on the level of system cost of a large-scale implementation of a DLC tariff.

*Keywords:* Monetary incentives, Direct load control, RCT, Demand response

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## 1. Introduction

Industrialized and emerging countries worldwide are implementing energy and climate policies to promote the energy transition, i.e. the transformation of the current energy systems mostly based on fossil fuels into systems dominated by renewable energies and energy-efficient technologies. A critical pillar of the energy transition is the electrification of the private transport sector and the residential heating sector. This implies that in the future these sectors will be dominated by the presence of electric vehicles (EV) and heat pumps, respectively.

The significant growth in electric vehicles and heat pumps will increase and modify the load curve of the electricity demand. In particular, some studies (Hardman et al. (2018), Yilamz et al. (2020)) have shown that electric vehicles tend to be charged more often in the early morning and late afternoon. A similar behavior in using heat pumps is also observed, i.e. heating services are more requested in the late afternoon and during the evening when most of the household members are home (Love et al. (2017), Yilamz et al. (2020)).

The change in the electricity demand and its load curve due to the increase of electric vehicles and heat pumps is expected to create periods of substantial peak demand that could determine problems for the electricity system, especially in balancing supply and demand (Guminski et al. (2019), Blonsky et al. (2019)). The increase in the use of renewable energy, characterized by high intermittent availability, is also likely to exacerbate these problems. One approach to solve these problems is to invest in production and distribution capacity to satisfy the peak electricity demand. However, from an economic point of view, this solution can be very inefficient because of the under-utilization of the grid during non-peak hours. An alternative approach to influence the shape of the load electric curve is to use pricing policies that incentivize consumers to move part of their demand during off-peak periods.

In this regard, time-of-use (TOU) tariffs have shown to be an interesting measure to reduce peak electricity demand and to shift the demand to off-peak periods (Klaassen et al. (2016), Sundt et al. (2020)). On top of peak load prices, several utilities have introduced another type of pricing strategy during the last few years to reduce the demand during peak hours, i.e. direct load control (DLC) tariffs. Under these tariffs, customers receive compensation for allowing the electricity provider to control, through an installed remote control switch system, the functioning of some appliances during peak hours of the day (Krarti (2018)). Despite the encouraging prospects of DLC, acceptance rates among customers across Europe are still low, with some evidence pointing to the lack of financial incentives as one main deterrent Yilmaz et al. (2022)) as well as low information and knowledge of consumers in residential electricity markets (Hortaçsu et al. (2017)).

The aim of this research is to explore the effectiveness of two strategies in promoting the uptake of a DLC tariff. The first strategy involves a video intervention that offers more detailed information about the tariff. The second strategy involves an upfront subsidy provided by the electricity company, which covers the costs of the remote control switch system installation and organization.

We analyze the impact of these two measures in the context of the activities of a Swiss electricity company that, unsuccessfully, introduced in 2022 a DLC tariff for residential customers who own electric vehicles or heat pumps.

To verify the impact of these measures in increasing the adoption of a DLC tariff, we organized two Randomized Control Trials (RCT). In a pre-phase of the study, we implemented an RCT using a stated choice approach to identify and verify the potential effectiveness of monetary incentives in promoting the adoption of a DLC tariff. For this purpose, we implemented a survey with 649 owners of electric vehicles. In this survey, we employed a contingent valuation protocol combined with an RCT to get information on the willingness to accept a DLC tariff under two scenarios. In the first scenario, participants were asked to cover the expenses for installing the remote control switch device needed for a DLC tariff, while in the second scenario, the cost of the device and its installation was covered by a subsidy offered by the local utility.

The results of this stated choice analysis showed that on average, customers are ready to accept a DLC tariff if the local electricity company grants an annual discount of approximately 80 CHF. Further, the results show that introducing an upfront subsidy positively impacts the adoption rate of a DLC tariff.

Given these results obtained in a stated choice context, we decided to test the impact of an upfront subsidy for the organization and installation costs of the remote control switch device in a real context. For this purpose, we organized a second RCT, the most important of this paper, with 1,500 customers owners of an electric vehicle and/or a heat pump divided into three groups (a control and two treated groups). With the same RCT we also decided to test the impact of a second treatment, an information treatment, on the functioning of a DLC tariff with its advantages and disadvantages. This treatment, in line with the consumer choice literature on framing effects, aims to test if framing and communicating the same information in another way impacts the adoption of a DLC tariff. Unfortunately, we had to exclude a treatment based on an annual discount from the revealed RCT because the local electricity company judged this treatment difficult to implement.

To the best of our knowledge, the paper's main contribution is to provide the first empirical evidence on the impact of monetary and information treatments on adopting a DLC tariff using an RCT based on revealed choices and not, as done so far, using stated choice methods. Moreover, an interesting aspect of the paper is that one of the treatments used in the revealed choice RCT is based on the results of a stated choice RCT.

The paper is structured as follows. Section 2 reviews the literature on direct load control tariffs, their barriers to acceptance, and incentives to overcome consumer inertia and increase adoption rates. In Section 3 we shortly present the results of the stated choice RCT whereas in Section 4 we discuss with more detail the revealed choice RCT. More specifically, Section 4.1 presents the experimental design, Section 4.2 outlines the data of the revealed-choice experiment, and in Section 4.3 we illustrate the main empirical results of the information and monetary intervention. In Section 5.1 we then present some simple back-of-the-envelope calculations of the effect of a DLC on the costs and revenues of a local electricity distribution company, whereas in Section 5.2 we present possible electricity system cost impacts of the introduction of a DLC tariff on a broader scale. Finally, Section 6 discusses and concludes.

## 2. Literature

This study combines various strands of literature, delving into barriers for DLC tariff acceptance and shedding light on the roles of informational and monetary incentives in the promotion of the adoption of this type of tariff. In this section, we first briefly mention the results of some studies that analyzed the barriers in the adoption of a DLC tariff. Then, in the second part, we discuss some important studies that analyze the role of monetary incentives and information on the choice of a DLC tariff.

Several studies in the literature analyzed the barriers to adopting a DLC tariff. Some studies analyze the role of distrust in the energy provider (Stenner et al. (2017), Soland et al. (2018)), the role of loss of control (Bailey and Axsen (2015)) and the privacy concerns (Murtagh et al. (2014), Moser (2017)) of adopting a DLC tariff. On the other hand, Fell et al. (2015) surveyed 2,002 bill-paying individuals in Great Britain and found that around 37% of respondents were willing to switch to a DLC tariff, despite its inherent loss of control associated with DLC; conversely, only between 25-30% of the sample were open to accepting any of the proposed TOU tariffs. On another note, Bossi et al. (2013) and Soland et al. (2018) emphasize how DLC acceptance rates depend on the type of affected appliances, and Yilmaz et al. (2020) concludes that rates are higher for devices (e.g. heat pumps, electric boilers) than for appliances (e.g. EV charging stations, dishwashers).

Although scarcer in terms of evidence, another main strand of literature looks at the presence of consumer inertia and switching costs[1] as a key explanation of why alternative tariffs like DLC tariffs are not as adopted as desired. Hortaçsu et al. (2017) documents the presence of search frictions and inattention in the Texas electricity retail market and points at low-cost informational campaigns as effective solutions to increase customer surplus. Within

[1] First defined by Kahneman et al. (1991) as "status-quo bias".

their literature review on consumer responses experiments and inattention, Harding and Sexton (2017) confirm that ”consumers are uninformed about their electricity consumption habits and unwilling to make nominal investments to learn”. In this context, automation technology and, more generally, information provision can effectively help eliminate this bias from demand response. Similar findings have been supported by Ito et al. (2017) and Dressler and Weiergraeber (2023).

The literature is also rich of studies analyzing the role of monetary incentives and informational campaigns on the adoption of DLC tariffs. For instance, several studies analyze the role of annual compensation provided by the local electricity provider to the customers for DLC subscription, whereas others consider the impact of additional upfront monetary incentives. Stated-choice experiments looking at the willingness to accept (WTA) DLC tariffs are the most common design to address the question of how financial incentives help increase adoption rates. Under the studies in Broberg and Persson (2016), Richter and Pollitt (2018), Ruokamo et al. (2019), the willingness to accept external control over household electricity and heating services requires a compensation of around 169 CHF/year, 38 CHF/year and 213 CHF/year, respectively[2]. Xu et al. (2018) finds that, although an annual compensation as low as 30 USD can increase DLC stated acceptance rates, a DLC override option appears to be more appealing. Ruokamo et al. (2019) concludes that compensation varies for electricity (up to 199 EUR annually) compared to heating services (up to 80 EUR). In the Swiss context, Yilmaz et al. (2022) performs a stated-choice experiment on 556 respondents to their elicit preferences for DLC tariff applied to EV charging stations and heat pumps under different characteristics (10CHF to 60CHF annual compensation, 1 bloc per day or 20 blocs per year, override option availability, different time frames of curtailment). Using a latent-class model, they find that approval rates range between 33% and 71%, that a higher financial compensation boosts the DLC adoption directed to heat pumps, and that for EV

[2]It is important to note that the WTA values in the stated-choice literature highly vary depending on the characteristics of the tariff (e.g. the appliances affected, the amount of blocs and their duration).

charging stations the override option performs better. Finally, in the only genuine upfront incentive stated-choice experiment we could find (i.e. Ito et al. (2017)), participants that received an additional upfront incentive of 60 USD were 17 p.p. more likely to switch to the proposed time-variant tariff, compared to the reference group that only received an estimate of their expected gains from switching. Overall, however, the literature on the impact of such upfront monetary incentives on DLC tariffs, specifically, is nearly absent.

Another strand of the literature analyzes the effect of low-cost informational campaigns that try to reduce consumer inertia and inattention (Burkhardt et al. (2019), Ito et al. (2018), Nicolson et al. (2017), Stenner et al. (2017)) on the adoption of DLC tariffs. More recently, within their online field experiment Berger et al. (2022) find that advertisement on technology (i.e. smart meters) is more impactful when the focus of the campaign is on savings, compared to environmental or technological concerns. Differently, Schwartz et al. (2015) finds that combining the advertisement of monetary together with environmental benefits of an energy-saving program can backfire, since being shown monetary savings can undermine the intrinsic motivation of already environmentally concerned consumers. More interestingly in our context is the impact of information framing and presentation format on consumer choices, where the literature seems to agree that dynamic images (compared to static ones or texts) have more impact in increasing consumer involvement and product recollection (Roggeveen et al. (2015), Nasco and Bruner (2007), Hsieh and Chen (2011)), although none of these studies applies to the power retail industry.

In the existing literature, no study was found that performs a revealed choice RCT to analyze the impact of framing information and upfront monetary incentives on revealed DLC tariff adoption. As discussed in the literature, stated-choice experiments can be affected by a hypothetical bias (e.g. Murphy et al. (2005), Joshi and Rahman (2015) Menapace and Raffaelli (2020)). Therefore, performing choice experiments on DLC tariff in a revealed choice setting is extremely important. In this regard, the present study hopes to fill this gap in the literature.

## 3. Stated choice RCT and monetary treatments effectiveness

In this section, we provide a concise overview of the stated-choice randomized controlled trial (RCT) conducted in the initial phase of our empirical analysis. The primary objective of this step was to assess and validate the potential effectiveness of monetary incentives as means to encourage the adoption of a DLC tariff. The presentation of the results from this stated experiment will be brief, as its primary purpose is to provide valuable insights to inform the primary empirical analysis of this paper based on revealed choices. Additionally, it is worth noting that stated-choice analyses are susceptible to the above-mentioned hypothetical bias, and as such their outcomes must be approached with caution. Nonetheless, we believe that this form of hypothetical analysis can offer valuable insights for designing treatments that can be subsequently implemented in a real-world context.

In this stated-choice RCT, we were primarily interested in using a contingent valuation (CV) protocol to estimate the willingness to accept (WTA) a DLC tariff under two situations. In the first, the local electricity company covers the installation cost of the remote control switch device needed to implement this tariff, whereas in the second, the customer has to pay for it. The motivation for applying a WTA protocol is based on the fact that, as mentioned in the previous sections, a DLC tariff creates discomfort for the client because it limits the possibility of consuming electricity during some predefined periods. For this reason, an electricity company that wants to introduce a DLC tariff generally proposes to the customer a discount on the electricity price or a fixed financial contribution per year as compensation for the discomfort. Consequently, we have estimated the value of the necessary compensation by analyzing answers that customers have provided to a contingent valuation protocol.

To estimate the stated WTA we implemented an online survey with a sample of owners of electric vehicles living in the Italian part of Switzerland. The survey has been organized in cooperation with the company that owns and manages the public charging stations in the region. Within the survey, we first illustrated the purpose of a DLC tariff as a measure to prevent episodes of peak electricity demand. Then, we presented the general characteristics of this type of tariff: maximum frequency of blocks, duration of each block, installation costs of the DLC remote control system, and annual electricity discount. Afterward, we gathered the yearly willingness to accept (WTA) compensation to adopt a DLC tariff via a single-bounded dichotomous choice question. More specifically, in line with standard contingent valuation (CV) protocols, we presented different levels of annual compensation to the participants of the experiment, and to some of them the treatment, i.e. the installation-cost upfront discount. We then provided them with a dichotomous question (yes/no) on whether they would accept such a tariff (see Table 1).

Table 1: Question on the approval of the DLC tariff

> **Question 35.** Let's assume that your local electric utility is considering measures to prevent episodes of excessive electricity demand. One such measure involves a new electricity tariff for households that have a charging station for electric or plug-in hybrid cars. If you do not own a charging station in your home, imagine owning one.
>
> The tariff has the following conditions:
>
> - Each day, the charging station can be disconnected for a maximum of 3 times, with a maximum duration of 2hrs per block;
> - Between each disconnection there is a guaranteed free time of at least 2hrs;
> - The installation of the remote control system has to be done once and [**it is at your expenses (about 100 francs)|it is paid by the energy provider**].
>
> Would you be willing to switch to this new tariff in exchange for a discount of [**24|48|72|96|120**] francs per year on your bill?

*Notes:* Translation in English of the contingent valuation question in the survey. In bold the two varying conditions (i.e. the availability of an installation-cost discount on the remote switch device, and the level of annual discount), that were presented randomly to respondents.

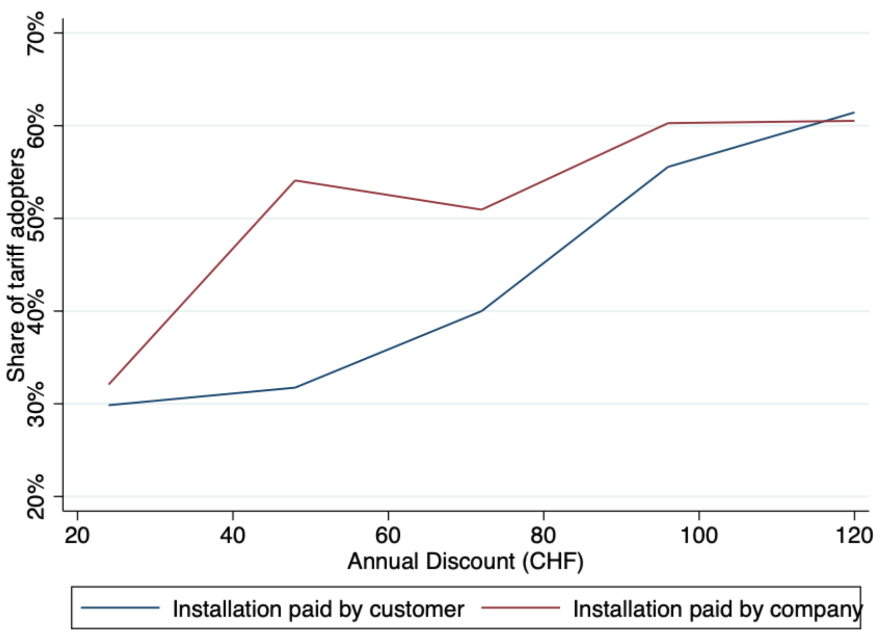
The question was coded according to two variables. The first one is a continuous variable representing the level of the annual discount in the electricity bill when subscribing to the tariff, and taking for each respondent a random value among 24, 48, 72, 96 or 120 CHF[3]. The

[3]To allow for a better understanding of the discount size, respondents were informed that in 2022 the average annual bill for a household consuming 4500 kWh was of around 954 CHF.

second variable (i.e. installation-cost treatment) represents the conditions of installation of the DLC remote controller. This variable randomly takes the value of 1 when the installation costs (approximately 100 CHF) are covered by the energy provider (treatment group), and of 0 when the installation costs are required to be covered by the client (control group)[4]. By randomizing the upfront installation cost coverage, we were able to assess how the availability of the upfront subsidy affects tariff acceptance across different levels of annual discount.

The final sample for this hypothetical choice experiment comprises 649 responses, with 333 being part of the control group and 316 being part of the installation treatment group[5].

Figure 1: Tariff acceptance rates for the installation treatment and control groups, across different levels of annual discount (survey data)




*Notes:* Evidence of an acceptance gap between the treatment and control groups (red and blue lines, respectively). The two curves display similar slopes, but at each level of annual discount below 120 CHF, the installation treatment group's acceptance rate is above the control group's.

[4]In both survey and real-case experiment, people in the control group are informed about the cost of the remote control installation, while treated people are only informed that the installation process will be paid and managed by the energy provider.

[5]In Appendix A we included more information about this CV analysis. In Appendix Table A.3 we provide information on the randomization by annual discount for the control and installation treated groups. Further, in Table A.4 we compare selected respondents' characteristics between the treatment and control groups to support the assumption of unconfoundedness of treatment allocation.

The first way of presenting the results of this analysis consists of graphically illustrating an acceptance curve that shows the percentage of yes-responses at each level of the proposed annual compensation bids. The percentage of positive responses to WTA bids is expected to increase monotonically. Figure 1 presents a plot of the acceptance rate conditional on installation treatment and on the level of annual discount. The two lines, one for the treated group and the other for the control group, support the consistency of responses and indicate that the WTA of treated respondents (blue line) is lower than the one of respondents in the control group (red line)[6]. In addition, Figure 1 motivates an econometric analysis to estimate the impact of the upfront subsidy on the adoption rate of a DLC tariff. For this purpose, we estimated the following logit econometric model:

$$\mathbb{P}\left[\mathbb{1}_i\right] = \alpha_0 + \alpha_{i,1} t_i + \alpha_{i,2} d_i + \boldsymbol{\delta}_i \mathbf{z}_i + \eta_i \tag{1}$$

where $i$ stands for each individual response collected, $\mathbb{1}_i$ is the binary answer to the dichotomous acceptance question, $t_i$ is the dummy for the presence of the upfront subsidy to cover the installation cost, $d_i$ represents the bids corresponding to the different proposed levels of annual discount (24 CHF to 120CHF), $\mathbf{z_i}$ is a vector of household and house variables collected within the survey and $\eta_i$ are the error terms.

Under the logit model results in Table 2, both the annual discount and the upfront installation-cost subsidy positively affect the probability of accepting the tariff proposed in the survey, even when adding further household and house characteristics. More specifically, the presence of an installation subsidy is associated with a statistically significant increase of around 8 p.p. in the probability that the respondent accepts the proposed tariff. Furthermore, the impact of the subsidy is positive and significant across all different values of annual discount.

[6]The average value of the WTA of the control group is approximately 90 CHF whereas, as expected, it decreases to around 65 CHF for the treated group that receives an upfront subsidy.

Table 2: Logit model for the probability of accepting the tariff (survey data)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Installation=1 | 0.0814** | 0.0856** | 0.0908** | 0.0874** |
| | (0.0401) | (0.0415) | (0.0421) | (0.0422) |
| Discount | 0.317*** | 0.330*** | 0.340*** | |
| | (0.0601) | (0.0633) | (0.0634) | |
| Discount=48 | | | | |
| Installation=0 | | | | 0.0430 |
| | | | | (0.0837) |
| Installation=1 | | | | 0.214** |
| | | | | (0.0958) |
| Discount=72 | | | | |
| Installation=0 | | | | 0.126 |
| | | | | (0.0828) |
| Installation=1 | | | | 0.166* |
| | | | | (0.0997) |
| Discount=96 | | | | |
| Installation=0 | | | | 0.270*** |
| | | | | (0.0837) |
| Installation=1 | | | | 0.288*** |
| | | | | (0.0920) |
| Discount=120 | | | | |
| Installation=0 | | | | 0.330*** |
| | | | | (0.0838) |
| Installation=1 | | | | 0.315*** |
| | | | | (0.0894) |
| HH controls | No | Yes | Yes | Yes |
| House controls | No | No | Yes | Yes |
| Observations | 649 | 646 | 646 | 646 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Notes:* This table illustrates estimates of the marginal effect of the installation-cost treatment on the DLC acceptance rate using survey data. Household controls include home-ownership, household size, income, work status, and social status. House controls include whether the house is a single-detached house, the availability of charging infrastructure (both charging station and cable), and of solar panels and heat pumps. In the last column, we present the estimates of the interaction between the annual discount and the installation treatment, with the annual discount at 24 CHF representing the reference level.

The results of this stated-choice RCT suggest that, at least in a hypothetical choice setting and for owners of electric vehicles, the two monetary incentives, i.e. annual discount and upfront installation-cost subsidy, positively influence the adoption rate of a DLC tariff. Given this information, we decided to test one of these measures (i.e. the upfront installation-cost subsidy) in a real choice setting by implementing an RCT with, in this case, customers that own an electric vehicle and/or a heat pump[7]. In the following sections, we will present this experiment.

## 4. Revealed choice RCT

We organized the revealed choice RCT in cooperation with a local electricity and gas distribution company. This company serves approximately 97,000 households living in the city of Lugano and in its surrounding areas. Since 2022, the company has introduced a DLC tariff known as the "Tariffa Flessibilità" for its customer base. However, since its introduction, this tariff has attracted scarce attention from clients and has achieved only minimal levels of adoption.

The "Tariffa Flessibilità" primarily targets clients who possess either an EV charging station, a heat pump, or both. The commercial conditions of this tariff are the following: (1) Reduction in electricity price during peak periods by 1 cts/kWh; (2) Costs of purchasing and installing the remote control device to be borne by the customer (approximate cost of 300 CHF); (3) Appliances can be stopped or their power can be reduced for short periods of one or a maximum of two hours. These tariff conditions align more or less with the conditions of the tariff proposed in the stated choice RCT. However, while in the contingent valuation protocol presented in Table 1 the proposed annual discount varied from 24 CHF to 120 CHF, in the present RCT the discount level is fixed. Indeed, for a single-family residence equipped with an EV charger and a heat pump, a reduction in electricity price during peak periods

[7]As already mentioned in the introduction, due to implementation issues at the level of the local utility, i.e. a partner in the organization of the RCT, we were not able to test in the revealed choice RCT the effect of different annual discounts on the adoption of a DLC tariff.

by 1 cts/kWh translates to an approximate annual discount of 100 CHF. Furthermore, in the protocol used in the choice experiment, we assumed 100 CHF as the installation cost for the DCL remote controller, not 300 CHF. However, note that the actual installation cost of the DCL remote controller can vary depending on the age of the building's electrical system, and it can range from 100 CHF to 500 CHF.

### *4.1. Experimental design*

The main goal of this randomized controlled trial is to evaluate whether, in a revealed setting, owners of EV charging stations and heat pumps are more willing to subscribe to a DLC tariff when the electricity distribution utility takes charge of the organization and installation cost of the DLC remote control system (i.e. installation-cost treatment). As already anticipated, we also decided to verify the impact of information framing and presentation format on adopting a DLC tariff. As discussed in the literature section, several studies suggest that dynamic images (compared to static ones or texts) have more impact on increasing consumer involvement and attention to new products. For this purpose, we introduced a video treatment as part of the RCT setting.

In order to do so, the local provider agreed to contact via mail a total of 1,500 clients, who were randomly selected among eligible clients of the tariff, i.e. owners of EV charging stations and heat pumps in April 2023. Clients were randomly assigned to one of the three following groups, each composed of a total of 500 individuals:

1. A control group, who received a brochure that outlined the standard conditions for the tariff (see Figure Appendix C.1);
2. A video treatment group, who received a brochure that outlined the standard conditions for the tariff, plus an additional QR-code to access a video presenting the same information contained in the brochure (see Figure Appendix C.2). The video was linked to a dedicated and unindexed page on the energy provider website, to ensure that only owners of the brochure could access the content. In Appendix Table C.1 we present a transcript of the video.

3. An installation-cost treatment group, who received a brochure outlining the standard tariff conditions with one exception. Differently from the other groups, for this treated group the electricity distribution utility takes charge of the organization and installation cost of the DLC remote control system needed for the functioning of the DLC tariff (see Figure Appendix C.3).

Attached to the brochures, clients received an accompanying letter (see Appendix C.2 and C.3), and were invited to contact the provider between April and June 2023 to express their interest in the tariff. Clients could contact the provider either via email or via phone call. Out of the 1,500 brochures sent, 38 of them were not delivered correctly because of the wrong address and were sent back to the energy provider (more specifically, 8 for the control group, 16 for the video treatment group, and 14 for the installation treatment group). The maximum possible amount of observations for which we have outcome variables is 1,462. Further, as illustrated in Figure Appendix B.1, some customers within this sample specification show a very high and atypical annual electricity consumption for residential customers. Most likely, these are atypical residential customers who also run a small commercial activity in the house. Because the focus of the study is on typical residential customers, we decided to perform the main empirical analysis excluding the customers with an electricity consumption higher than 50'000 Kwh. Applying this threshold, we further excluded 148 clients from the main analysis, reaching a maximum number of observations of 1,314. Further, we had to exclude 6 observations because of missing information on some control variables used in the econometric analysis. The final sample (i.e. excluding missing outcome or control variables) is then composed of a total of 1,308 clients.

To exclude the possibility that the results are influenced by the exclusion of the large atypical consumers, as a robustness check we performed the empirical analysis also considering these customers.

*4.2. Data and sample characteristics*

In Table 3, we provide a summary statistics of the sample covariates. In the first five lines we present summary statistics on some individual characteristics of the participants in the RCT, whereas in the remaining part of the table, we illustrate summary statistics for some aggregate variables such as income and age structure of the municipalities where these participants live. We have to rely on aggregate variables for some socio-economic variables since we could not organize a survey with the participants of the RCT to collect this information at the individual level.

In terms of appliances owned, almost three clients out of four own a heat pump, while the rest owns charging stations. Only a handful of clients possess both devices. With respect to electricity consumption, we have information on past consumption in 2021 and 2022. Mean and median consumption values are 10,135 and 8,375, respectively.

Table 3: Summary statistics of covariates

| | count | mean | sd | min | max |
|---|---|---|---|---|---|
| Charging station | 1308 | 0.27 | 0.44 | 0 | 1 |
| Heat pump | 1308 | 0.73 | 0.45 | 0 | 1 |
| Both appliances | 1308 | 0.01 | 0.07 | 0 | 1 |
| Average annual consumption (kWh) | 1308 | 10135.08 | 7584.38 | .5 | 48952 |
| Population (municipality) | 1308 | 17668.80 | 37406.42 | 299 | 420217 |
| Share of women (municipality) | 1308 | 0.51 | 0.01 | .4573832 | .5411444 |
| Share of single houses (municipality) | 1308 | 0.36 | 0.17 | .0276289 | .7741935 |
| Share of people over 65 years old (municipality) | 1308 | 0.22 | 0.03 | .1271008 | .3028322 |
| Mean income (municipality) | 1308 | 84.54 | 17.50 | 62.62 | 195.53 |
| Observations | 1308 | | | | |

*Notes:* Average annual consumption is composed by dividing total consumption (i.e. the sum of four variables of day consumption in 2021, night consumption in 2021, day consumption in 2022 and night consumption in 2022) by the number of years (i.e. two years).

To assess the validity of the random assignment assumption after excluding the large atypical consumers, we performed a t-test on the difference between the individual covariates in the control group and the video treatment group (Table 4), and the control group and the installation treatment group (Table 5). As expected, no statistically significant differences were observed between these pairs of groups. Additionally, we conducted F-tests to examine the overall difference between covariates in the control group and the treatment groups. We found no evidence that the covariates significantly influence treatment assignment.

Table 4: Balancing test for the video treatment

| | Control | | | Video | | | |
|---|---|---|---|---|---|---|---|
| | n | mean | sd | n | mean | sd | Diff |
| Charging station | 440 | 0.26 | 0.44 | 432 | 0.25 | 0.44 | -0.014 |
| Heat pump | 440 | 0.73 | 0.44 | 432 | 0.74 | 0.44 | 0.017 |
| Both appliances | 440 | 0.00 | 0.07 | 432 | 0.00 | 0.07 | -0.002 |
| Average annual consumption (kWh) | 440 | 10146.21 | 6858.18 | 432 | 10211.98 | 8044.09 | 2,544.173 |

Table 5: Balancing test for the installation treatment

| | Control | | | Installation | | | |
|---|---|---|---|---|---|---|---|
| | n | mean | sd | n | mean | sd | Diff |
| Charging station | 440 | 0.26 | 0.44 | 436 | 0.28 | 0.45 | 0.022 |
| Heat pump | 440 | 0.73 | 0.44 | 436 | 0.71 | 0.45 | -0.025 |
| Both appliances | 440 | 0.00 | 0.07 | 436 | 0.01 | 0.08 | 0.001 |
| Average annual consumption (kWh) | 440 | 10146.21 | 6858.18 | 436 | 10047.66 | 7825.58 | 1,540.942 |

### *4.3. Empirical results*

In the empirical analysis we considered two outcome variables, i.e. the number of contacts to the energy provider to get more information on the DLC tariff and the number of new subscriptions to this tariff. The decision to consider also the number of contacts as an outcome variable is based on the fact that the period considered after the treatment was only two months, which is likely to be a short time span for customers to complete the process of subscription. Additionally, it provides a good benchmark to compute how many of the clients who appear to be interested in the tariff are eventually willing to switching to it.

In Table 6 we present a summary statistics of the number of clients who contacted the energy provider and the number of clients that subscribed to the tariff based on treatment assignment. Approximately 8% of the total sample reached out to the provider, with a quarter of these switching to the DLC tariff. Among the 121 clients who contacted the energy provider, approximately 53% of them belonged to the installation treatment group, around 28% were linked to the video treatment group and only 19% belonged to the control group. In terms of new subscribers (34 in total), roughly 61% were from the installation treatment group, around 32% from the video treatment group, and around 7% included in the control group. In terms of the video treatment, most of the treated clients that contacted the electricity company or adopted the DLC tariff did watch the video between April 18th and June 30th. The summary statistics presented in Table 6 suggest that both treatments have an impact on the two outcome variables.

Table 6: Summary statistics of the outcome variables

| | **Contacts** | | **Subscriptions** | |
|---|---|---|---|---|
| | Freq. | Percent | Freq. | Percent |
| **Total sample:** | | | | |
| No | 1341 | 91.72 | 1428 | 97.67 |
| Yes | 121 | 8.276 | 34 | 2.326 |
| Total | 1462 | 100 | 1462 | 100 |
| **Control group:** | | | | |
| No | 470 | 32.15 | 490 | 33.52 |
| Yes | 22 | 1.505 | 2 | 0.137 |
| Total | 492 | 33.65 | 492 | 33.65 |
| **Video treatment group:** | | | | |
| No | 450 | 30.78 | 473 | 32.35 |
| Yes | 34 | 2.326 | 11 | 0.752 |
| Total | 484 | 33.11 | 484 | 33.11 |
| **Installation treatment group:** | | | | |
| No | 421 | 28.80 | 465 | 31.81 |
| Yes | 65 | 4.446 | 21 | 1.436 |
| Total | 486 | 33.24 | 486 | 33.24 |

*Notes:* In the above box, we present a summary of all number of contacts and subscriptions for the total sample. In the boxes below the double horizontal line, the summary of outcome variables is differentiated by treatment assignment.

To get more precise information on the impact of the video and the installation cost treatment on the two main outcome variables, we estimated a logit and a linear probability model using the following specification:

$$\mathbb{P}\left[\mathbb{1}_i\right] = \beta_0 + \beta_{i,1} t_i + \boldsymbol{\gamma}_i \mathbf{z}_i + \epsilon_i \tag{2}$$

where $i$ stands for each client, $\mathbb{1}_i$ is the binary outcome variable (i.e. "contact" or "subscription"), $t_i$ is the dummy for the treatment performed ("video" or "installation" treatment),

$\mathbf{z_i}$ is a vector of individual characteristics (e.g. energy consumption, device installed, average socio-economic variables based on the individual's residence area) and $\epsilon_i$ are the error terms.

Starting from a basic model where the outcome variable is regressed on the video and installation treatment variables exclusively (column 1), we progressively add the control variables presented in Table 3 (columns 2-4). Electricity consumption is included as mean annual consumption across the two years (in the third column). In column 4, we also include controls at the municipal level, such as mean income, population, share of women, share of people over 65 years old and share of single houses[8].

The econometric results reported in Table 7 refer to the model specifications with the number of contacts as a dependent variable. The results show a clear and statistically significant impact of the installation-cost treatment. The results are similar across the different model specifications (columns 1-4) and across the econometric model (logit and linear probability model). Being offered an installation cost treatment increases the probability of contacting the provider by around 10 percentage points compared to the control group. The results also indicate that the impact of the video treatment is only confirmed in the linear probability model and only at a level of significance of 10 percent. As expected, when adding covariates to the model the magnitude of estimates decreases for both treatments. Finally, under all model specifications, we find no evidence of the two treatment estimates being possibly statistically equivalent to each other.

In Table 8 we present the results with the number of subscriptions as the dependent variable. Also in this case, the results show a clear and statistically significant impact of the installation-cost treatment. The results are similar across the different model specifications (columns 1-4) and across the econometric model (logit and linear probability model). Being offered an installation-cost treatment increases the probability of adopting the new DLC tariff by around 7 percentage points compared to the control group. The results also indicate that

[8] We do not cluster standard errors over any dimension available, since we can rely on the random assignment assumption; as discussed by Abadie et al. (2022), in similar cases clustered standard errors might be unnecessarily conservative.

Table 7: Probability of contacting the energy provider

(a) Panel A: Logit model specification

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0374 | 0.0376 | 0.0375 | 0.0375 |
| | (0.0237) | (0.0239) | (0.0239) | (0.0235) |
| install=1 | 0.0996*** | 0.0996*** | 0.0996*** | 0.0988*** |
| | (0.0256) | (0.0260) | (0.0260) | (0.0258) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1314 | 1308 | 1308 | 1308 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(b) Panel B: Linear probability model specification

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0267* | 0.0263* | 0.0263* | 0.0274* |
| | (0.0159) | (0.0156) | (0.0156) | (0.0157) |
| install=1 | 0.0874*** | 0.0856*** | 0.0857*** | 0.0869*** |
| | (0.0190) | (0.0188) | (0.0188) | (0.0189) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1314 | 1308 | 1308 | 1308 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Notes:* Panel (a) presents the marginal effect estimates for the logit model, while panel (b) presents the marginal effect estimates for the linear probability model. The number of observations in the first column is 1,314, and it decreases to 1,308 in the following columns since, for some observations, individual and municipality controls are not available.

the impact of the video treatment is confirmed in both econometric specifications, although in the logit model at a level of significance of only 10 percent.

Table 8: Probability of subscribing to the tariff

(a) Panel A: Logit model specification

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0396* | 0.0376* | 0.0373* | 0.0352* |
| | (0.0219) | (0.0210) | (0.0210) | (0.0205) |
| install=1 | 0.0684*** | 0.0654** | 0.0653** | 0.0635** |
| | (0.0266) | (0.0259) | (0.0259) | (0.0262) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1314 | 1308 | 1308 | 1308 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(b) Panel B: Linear probability model specification

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0186** | 0.0185** | 0.0185** | 0.0187** |
| | (0.00791) | (0.00785) | (0.00786) | (0.00805) |
| install=1 | 0.0412*** | 0.0409*** | 0.0409*** | 0.0418*** |
| | (0.0105) | (0.0105) | (0.0105) | (0.0105) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1314 | 1308 | 1308 | 1308 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Notes:* Panel (a) presents the marginal effect estimates for the logit model, while panel (b) presents a the marginal effect estimates for the linear probability model. The number of observations in the first column is 1,314, and it decreases to 1,308 in the following columns since for some observations individual and municipality controls are not available.

Finally, we performed several robustness checks in order to exclude that the empirical results are driven by the exclusions from the analysis of the atypical large consumers. For this purpose we have estimated equation 2: a) using all observations, i.e. including the atypical large customers; b) using a lower threshold of annual consumption (30,000 kWh) to select the sample; c) excluding 5 percent of the observations with the lowest and highest electricity consumption values. The results of these robustness checks are reported in Appendix Tables

B.1 to B.6, and confirm the results just presented for Table 8 and Table 7. Balance tests confirm a correct randomization of these samples too. Finally, when introducing interaction terms between the treatment variables and the types of appliances owned, our analysis does not find evidence of treatment effects on either of the outcome variables being contingent on the specific devices possessed by the participants.

## 5. Economic implications

In this section, we will use some of the empirical results presented in the previous sections for two simple exploratory analyses of the economic implications of introducing a DLC tariff. The first analysis aims to understand the economic impact of introducing a DLC tariff for the local electricity distribution company. We are interested in determining the conditions under which the company has an economic incentive to subsidize the installation of devices required for a DLC tariff. The second analysis provides information on the impact of introducing a DLC tariff by all Swiss electricity utilities on the wholesale electricity market price and the total system cost of electricity production.

### *5.1. Cost-revenue*

In this section, we briefly outline the possible cost-revenue implications for a local electricity provider in offering a DLC tariff with the upfront subsidy of 300 CHF. It is important to underline that in this analysis, we assume that introducing a DLC tariff is not likely to broadly and significantly impact wholesale prices, hence allowing for the market price to maintain an off/on-peak differential. In other words, we still assume electricity prices to vary throughout the day[9]. Additionally, since this is not within the main scope of the present study, one should regard this as a back-of-the-envelope calculation, compared to a more structured cost-revenue analysis.

Based on the electricity consumption information for the new subscribers in our RCT,

[9]Please refer to the next section for a more in-depth analysis of system impacts.

we know that the median daytime consumption per year is around 6,100 kWh. Given that a DLC tariff gives the consumer a discount of 1 cents/kWh during the daytime period, the company loses around 61 CHF/client/year. Assuming the lifetime of the special device for the DLC tariff to be 20 years, the yearly cost per client and year for the device is 15 CHF. Hence, the cost per client for the local provider that adopts a DLC tariff is 76 CHF, corresponding to around 21 cents/client/day.

Regarding the possibility of realizing a gain, we assume that the local provider, can now block the electricity consumption of a heat pump or a BEV for a maximum of two hours per day. On average, heat pumps have an input power of around 10 kW, and charging stations for BEVs around 11 kW. Therefore, assuming the customer has only a BEV or a heat pump, the local provider can avoid purchasing electricity in the wholesale market during the peak period for approximately 20 kWh daily for the client. Of course, this electricity will be consumed during the off-peak period. Hence, for the local company, it is interesting to promote a DLC tariff only if the difference in the average price during the 2 hours and the average price during the remaining 20 hours is at least 1 cent per kWh.

It is important to note that in this computation, we do not include the possible avoided costs for the local provider to enhance grid capacity during high-peak hours. Still, the current analysis highlights that at wholesale price fluctuations similar to the current ones[10], proposing a DLC tariff is likely to be an economically profitable option for electricity retailers, even at low subscription rates.

### *5.2. System cost impact*

To assess in an exploratory way the system impact of the implementation of a DLC tariff under different levels of BEV or heat pump diffusion in Switzerland, we use a detailed partial-equilibrium model of the European electricity market with a particular focus on Switzerland.[11] The model determines the optimal hourly European dispatch using a

[10]As a reference, see the market data on EPEX SPOT website https://www.epexspot.com/en/market-data

[11]For a detailed presentation of the model and of the results see Appendix A in Cerruti et al. (2023)

yearly dispatch model minimizing total system costs. The model is calibrated to simulate prices, generation, and trading volumes for the year 2017. For the scenario analysis, load, renewable infeed, and capacities are updated to reflect the electricity system of the year 2030, to represent a credible time horizon for the chosen transition scenarios. The model used here builds on previous work with the model Swissmod as described in Abrell et al. (2019), Schlecht and Weigt (2014) and Demiray et al. (2017). The model covers 19 European countries [12] with a detailed representation of hydro-power and grid structures in Switzerland and aggregated structures for surrounding countries.

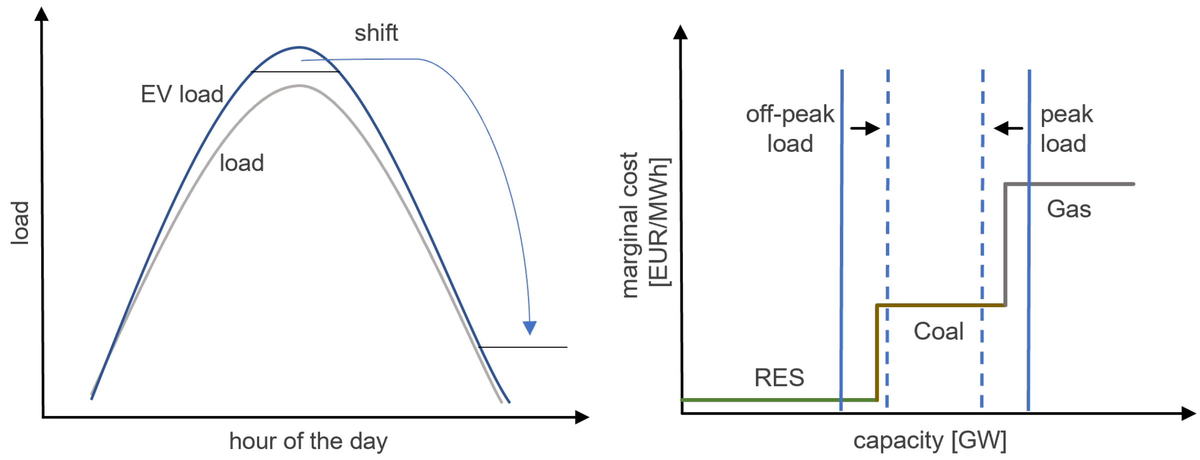
To understand intuitively how the DLC tariff affects an electricity market, we refer to Figure 2a. The graph shows a simplified daily load profile and the additional demand that can be determined by the utilization of electric vehicles (BEV) and/or heat pumps. Since the BEV and heat pump load usually correlates with the system load, it causes demand peaks. The DLC tariff helps to reduce these peaks and shift them to consecutive hours, thus reducing the load during the two hours of the highest demand.

In Figure 2b, we can see a simplified merit order for the Swiss power system, which includes three technologies: renewable generation (RES), coal, and a gas power plant. The DLC tariff allows for a decrease in the flexible BEV part of the system load during peak hours, resulting in lower prices during those hours. At the same time, it increases the off-peak load and prices during those hours. Of course, if the BEV and heat pump load are not highly correlated with the system load, then a DLC tariff is less interesting.

The simulation of the impact on the wholesale price and on the system costs based on a partial equilibrium model is performed by assuming that customers can choose to have a DLC tariff, and by assuming a compulsory DLC tariff. To perform such simulation, it is essential to have accurate information about the load curve of BEVs and heat pumps. In this simulation, we have assumed that the load curve for both technologies is similar, as shown in

[12] The countries include Switzerland as well as Austria, Germany, France, Italy, Belgium the Czech-Republic, Denmark, Spain, Great Britain, Hungary, Luxembourg, the Netherlands, Norway, Poland, Portugal, Sweden, Slovenia and Slovakia.

Figure 2: Illustration of the impact of introducing direct load control on the day-load profile (panel a) and on the merit order curve (panel b)




(a) Load shift from DLC tariff during a single day

(b) Price effect from load shift for a single hour

Yilamz et al. (2020). We have also assumed that the load curve can be represented well by the data collected on the charging behavior of owners of BEVs from the first survey of this study. This data shows a positive correlation between Swiss electricity demand and additional BEV load, which means that some load peaks are made worse by BEV integration. However, when we consider net load instead of total load, this correlation almost disappears[13]. As a result, the impact on peak prices from an increase in BEVs and heat pump penetration is likely to be smaller than if only peak load were increasing due to their integration. Finally, it is however worth noting that the assumed load charging curve heavily influences the simulation results.

We have analyzed the impact on the wholesale price and system cost of an increase of the number of battery electric vehicles (BEVs) and heat pumps for 2030 using different scenarios. The first scenario, which serves as a reference point, assumes 0 BEVs and heat pumps. The second scenario assumes an integration of 0.5 million BEVs and/or heat pumps. This number reflects the number of BEVs anticipated for 2030 in the Swiss Energy Perspective 2050+ (0.5 million BEVs with a total load of 2.4 TWh). The final two scenarios assume a significant

[13]The net load is the gross load minus the wind and solar resource production.

increase in BEVs and heat pumps, with 1 and 2 million units, respectively. Additionally, we allow the curtailment of these technologies by up to 2 hours. In the case of an optional DLC tariff, we assumed an adoption rate of 4 percent, which is based on the results of our previous analysis that included the introduction of a subsidy for the installation of the device for this tariff. A plausible scenario with an optional DLC tariff, then, amounts to 20'000 BEVs and/or heat pumps.

Based on the simulation results, it has been found that implementing the DLC tariff in the model can help reduce the system cost and price impacts that come with the increased load of BEVs and heat pumps in Switzerland. The reduction in system costs in scenarios with a mandatory DLC tariff ranges from 2 million euros (0.5 million BEVs) to 16 million euros (2 million BEVs). On the other hand, in scenarios where a DLC tariff is optional and, therefore, has a low adoption rate and a small number of BEVs and heat pumps, the impact on system costs and wholesale price is significantly smaller. Generally, the results indicate that the impact of a DLC tariff on the cost of electricity systems is relatively minimal, and the same applies to its impact on wholesale prices.

In interpreting the results of this exploratory simulation, it is important to keep in mind that the results were obtained by making important assumptions regarding the configuration of the power system and the behaviour of BEV or heat pump owners. Changing these assumptions (e.g. the load curve of BEVs or of heat pumps) can significantly change the results. For this reason, we believe that these results are more practical in identifying the direction of possible effects than in accurately measuring them.

## 6. Conclusions

Countries worldwide are actively pursuing climate policies to facilitate the transition to renewable energy-based systems. A crucial aspect of this transition is the electrification of private transport and residential heating, leading to increased use of electric vehicles and heat pumps. However, this shift will likely increase peak electricity demand, thus creating further challenges to the electricity system balance. To avoid inefficient investments in production and distribution capacity to satisfy peak demand, electricity distribution companies may introduce direct load control (DLC) tariffs in a mandatory or optional form for owners of electric vehicle charging stations or heat pumps. In general, the DLC tariff offered in an optional form is not chosen so often. Therefore, the distribution companies have two options to increase the number of customers under this tariff, i.e., make it mandatory or introduce monetary incentives to promote its adoption.

This study provides empirical evidence on the impact of monetary and information interventions on DLC tariff adoption, combining revealed choices and stated choice methods. The empirical results suggest that to increase the number of customers that opt for a DLC tariff the local electricity distribution company could: (1) organize an information campaign on the functioning of a DLC tariff using different media approaches, including a video; (2) Take charge the organization and installation cost of the DLC remote control system need for this type of tariff.

However, it is acknowledged that both framing and monetary interventions may not be potent enough to significantly increase DLC adoption rates and shift peak demand. A more robust approach to encourage demand shifting could involve making DLC tariffs a mandatory contract for owners of heat pumps and charging stations. Nonetheless, this might come at the expense of decreased consumer surplus, as it could affect overall comfort. As a feasible alternative, we suggest defaulting eligible clients into DLC tariffs while allowing them the option to opt out. This approach is seen as the most economically viable and efficient solution for managing increased electrification while maintaining consumer flexibility.

Finally, it has been suggested that implementing a DLC tariff with an upfront subsidy could be economically beneficial for local providers, based on some simple back-of-the-envelope calculations and simulations. This is particularly true when there is a significant difference in price between peak and off-peak periods and when a DLC introduction does not heavily affect wholesale price differentials, as shown in our simulation. In this context, introducing a DLC tariff is unlikely to have a significant impact on system cost.

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## Appendix A. Survey design

The survey on EV usage and charging habits was filled in Italian through the platform *Surveymonkey*, and sent in November 2022 to 6500 owners of electric vehicles (either a battery electric vehicle, BEV, or a plug-in hybrid electric vehicle, PHEV) who are clients of the charging station provider *Emotí*. The response rate was around 10% (or 649 answers). On top of containing the discrete-choice question outlined in the previous section, the survey collects information at the household level on vehicle characteristics and vehicle usage, EV charging habits, house characteristics and household socio-economic variables.

Firstly, respondents in the survey were asked to answer the following questions on vehicle characteristics repeatedly (and separately) with respect to each car owned by their household. Since some households own more than one electric vehicle each, the total amount of EVs in the sample is 731, out of which 490 are battery-electric vehicles, and the remaining 241 are plug-in hybrid electric vehicles. See Appendix Table A.1 for a reference.

Table A.1: Summary statistics of EV usage (survey data)

| | count | mean | sd | min | max |
|---|---|---|---|---|---|
| EV is BEV | 731 | 0.67 | 0.47 | 0 | 1 |
| Year of purchase | 730 | 2020.12 | 2.01 | 2002 | 2022 |
| Range at full battery (in km) | 730 | 237.94 | 165.50 | 16 | 700 |
| Range at full battery (in km, BEV only) | 490 | 324.26 | 122.88 | 40 | 580 |
| Average yearly range (in km) | 731 | 14995.62 | 7630.50 | 0 | 50000 |
| EV is used daily for trip to work | 731 | 0.55 | 0.50 | 0 | 1 |
| EV is used daily for shopping | 731 | 0.19 | 0.39 | 0 | 1 |
| EV is used daily for leisure | 731 | 0.12 | 0.33 | 0 | 1 |
| Observations | 731 | | | | |

Secondly, EV charging habits were coded as a diary of charging occasions. For each day of the week, respondents were required to record their plug-in and plug-out hours, and specify which charger type was used for each charging event (i.e. home charging station, home charging cable, workplace charging station and public charging station). Thirdly, house characteristics included the type of housing (i.e. flat, detached house or semi-detached house) and the availability of technologies such as EV home charging (through charging cable or charging station), heat pumps and solar panels. With respect to EV charging technologies, respondents were asked to state their charging station power and whether their appliance includes the option of actively programming its charging hours. Household characteristics include to the total number of cars owned, household size, house ownership, education level, job position, civil status and income of the household (see Appendix Table A.2).

Table A.2: Summary statistics of EV consumer household and house characteristics (survey data)

| | count | mean | sd | min | max |
|---|---|---|---|---|---|
| Total cars in the household | 649 | 1.90 | 0.72 | 1 | 4 |
| EV as first car | 649 | 0.88 | 0.33 | 0 | 1 |
| Home owners | 649 | 0.40 | 0.49 | 0 | 1 |
| Employed | 649 | 0.82 | 0.38 | 0 | 1 |
| Income below 6,000 CHF | 649 | 0.18 | 0.39 | 0 | 1 |
| Income 6,001-9,000 CHF | 649 | 0.25 | 0.43 | 0 | 1 |
| Income 9,001-12,000 CHF | 649 | 0.23 | 0.42 | 0 | 1 |
| Income above 12,001 CHF | 649 | 0.20 | 0.40 | 0 | 1 |
| Household size | 649 | 2.65 | 1.23 | 1 | 5 |
| Household of 3 or more people | 649 | 0.56 | 0.50 | 0 | 1 |
| Degree | 649 | 0.61 | 0.49 | 0 | 1 |
| Day-night tariff | 649 | 0.54 | 0.50 | 0 | 1 |
| Single-family detatched | 649 | 0.52 | 0.50 | 0 | 1 |
| Solar panels | 649 | 0.76 | 0.43 | 0 | 1 |
| Heat pump | 649 | 0.38 | 0.49 | 0 | 1 |
| Home charging | 649 | 0.82 | 0.38 | 0 | 1 |
| Home charging via cable | 649 | 0.33 | 0.47 | 0 | 1 |
| Home charging via station | 649 | 0.49 | 0.50 | 0 | 1 |
| Home charging programming | 649 | 0.69 | 0.46 | 0 | 1 |
| Charging power below 11kW | 336 | 0.17 | 0.38 | 0 | 1 |
| Observations | 649 | | | | |

Finally, respondents were asked the DLC acceptance dichotomous question, coded accordingly to what presented in the main text. Randomization by annual discount for the control and installation treated groups is presented in Appendix Table A.3.

The target population of the survey was randomly allocated between the treatment and control groups. To support the unconfoundedness of treatment allocation and the validity of the experiment, in Table A.4 we present a comparison of selected respondents' characteristics between the treatment and control groups. A t-test between covariates for the two groups confirms that the average characteristics of respondents in the treatment and control groups are balanced with respect to all variables but, coincidentally, the ownership of heat-pumps (which is higher in the treated subsample) and some income brackets. We included these variables as additional controls in model specifications, to ensure that they

Table A.3: Installation treatment randomization, by proposed annual discount (survey data)

| | Freq. | Percent |
|---|---|---|
| Control group | | |
| 24 | 67 | 10.32 |
| 48 | 63 | 9.707 |
| 72 | 70 | 10.79 |
| 96 | 63 | 9.707 |
| 120 | 70 | 10.79 |
| Total | 333 | 51.31 |
| Installation treatment group | | |
| 24 | 53 | 8.166 |
| 48 | 61 | 9.399 |
| 72 | 53 | 8.166 |
| 96 | 73 | 11.25 |
| 120 | 76 | 11.71 |
| Total | 316 | 48.69 |
| Total | | |
| 24 | 120 | 18.49 |
| 48 | 124 | 19.11 |
| 72 | 123 | 18.95 |
| 96 | 136 | 20.96 |
| 120 | 146 | 22.50 |
| Total | 649 | 100 |

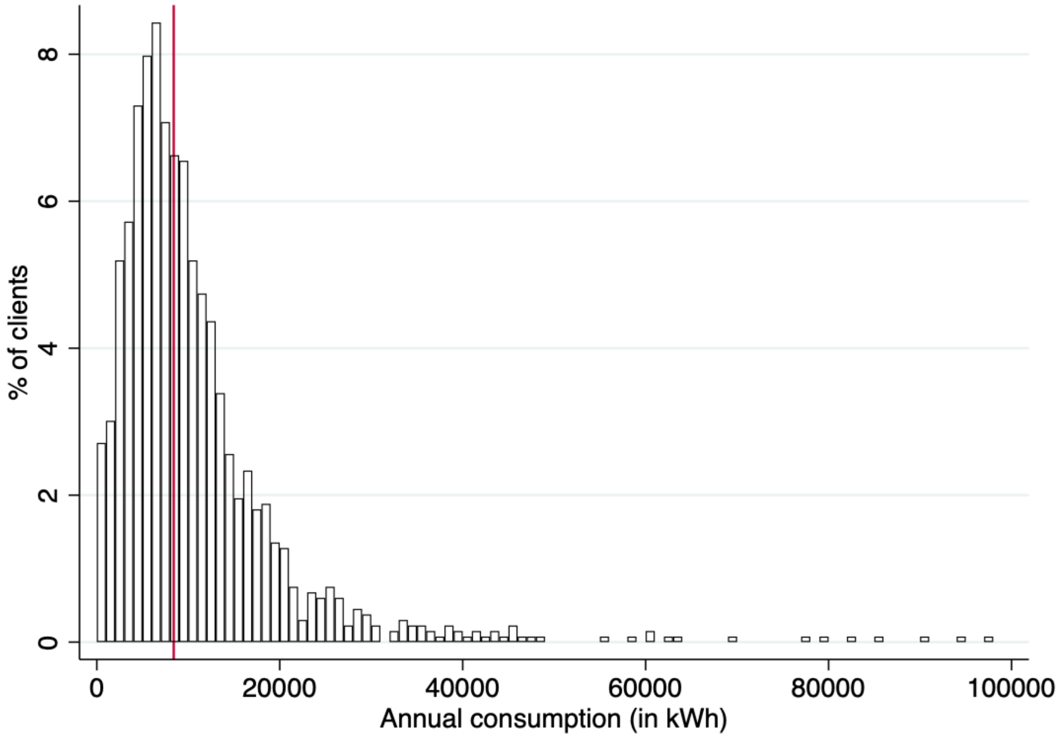
Table A.4: Balance test on observables

| | | Control | | | Treatment | | |
|---|---|---|---|---|---|---|---|
| | n | mean | sd | n | mean | sd | Diff |
| More than 1 car | 333 | 0.73 | 0.44 | 316 | 0.71 | 0.46 | -0.024 |
| EV as first car | 333 | 0.89 | 0.32 | 316 | 0.87 | 0.34 | -0.016 |
| Home owners | 333 | 0.40 | 0.49 | 316 | 0.40 | 0.49 | -0.007 |
| Employed | 333 | 0.82 | 0.39 | 316 | 0.83 | 0.38 | 0.009 |
| Income below 6,000 CHF | 333 | 0.15 | 0.36 | 316 | 0.22 | 0.41 | 0.068** |
| Income 6,001-9,000 CHF | 333 | 0.28 | 0.45 | 316 | 0.22 | 0.42 | -0.055 |
| Income 9,001-12,000 CHF | 333 | 0.21 | 0.41 | 316 | 0.25 | 0.43 | 0.040 |
| Income above 12,001 CHF | 333 | 0.23 | 0.42 | 316 | 0.17 | 0.38 | -0.054* |
| Household size | 333 | 2.61 | 1.19 | 316 | 2.68 | 1.26 | 0.074 |
| Household of 3 or more people | 333 | 0.54 | 0.50 | 316 | 0.57 | 0.50 | 0.032 |
| Degree | 333 | 0.62 | 0.49 | 316 | 0.61 | 0.49 | -0.002 |
| Day-night tariff | 333 | 0.56 | 0.50 | 316 | 0.53 | 0.50 | -0.030 |
| Single-family detatched | 333 | 0.52 | 0.50 | 316 | 0.53 | 0.50 | 0.006 |
| Solar panels | 333 | 0.76 | 0.43 | 316 | 0.76 | 0.43 | -0.000 |
| Heat pump | 333 | 0.42 | 0.49 | 316 | 0.34 | 0.48 | -0.082** |
| Home charging | 333 | 0.80 | 0.40 | 316 | 0.84 | 0.36 | 0.040 |
| Home charging via cable | 333 | 0.31 | 0.46 | 316 | 0.36 | 0.48 | 0.048 |
| Home charging via station | 333 | 0.50 | 0.50 | 316 | 0.49 | 0.50 | -0.008 |
| Home charging programming | 333 | 0.70 | 0.46 | 316 | 0.68 | 0.47 | -0.013 |
| Charging power below 11kW | 177 | 0.16 | 0.37 | 159 | 0.18 | 0.39 | 0.019 |

are not confounders that drive the results. Even though we observe only three variables as statistically different between the treatment and control groups, the F-test does not reject the joint significance of all observable characteristics included at a p-value of 0.0427.

## Appendix B. Figures and Tables

Figure Appendix B.1: Annual consumption (in 2021 and 2022), in kWh (experiment data, full sample)




*Notes:* The mean and median electricity consumption in this graph are 10,779 kWh and 8,406 kWh.

Table B.1: Logit model for the probability of contacting the energy provider (experiment data, full sample)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0359 | 0.0390* | 0.0321 | 0.0323 |
| | (0.0224) | (0.0228) | (0.0230) | (0.0226) |
| install=1 | 0.101*** | 0.105*** | 0.0938*** | 0.0937*** |
| | (0.0244) | (0.0251) | (0.0251) | (0.0249) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1462 | 1456 | 1335 | 1335 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.2: Logit model for the probability of subscribing to the tariff (experiment data, full sample)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0402* | 0.0387* | 0.0366* | 0.0345* |
| | (0.0211) | (0.0203) | (0.0203) | (0.0198) |
| install=1 | 0.0672*** | 0.0650*** | 0.0641** | 0.0623** |
| | (0.0256) | (0.0252) | (0.0255) | (0.0257) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1462 | 1456 | 1335 | 1335 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.3: Logit model for the probability of contacting the energy provider (experiment data, only observations below 30,000 kWh of annual consumption)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0362 | 0.0362 | 0.0367 | 0.0364 |
| | (0.0239) | (0.0241) | (0.0240) | (0.0235) |
| install=1 | 0.0974*** | 0.0973*** | 0.0979*** | 0.0972*** |
| | (0.0257) | (0.0260) | (0.0260) | (0.0257) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1278 | 1272 | 1272 | 1272 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.4: Logit model for the probability of subscribing to the tariff (experiment data, only observations below 30,000 kWh of annual consumption)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0406* | 0.0386* | 0.0387* | 0.0358* |
| | (0.0223) | (0.0214) | (0.0214) | (0.0207) |
| install=1 | 0.0669** | 0.0640** | 0.0643** | 0.0614** |
| | (0.0264) | (0.0257) | (0.0258) | (0.0259) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1278 | 1272 | 1272 | 1272 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.5: Logit model for the probability of contacting the energy provider (experiment data, electricity consumption 5% tails excluded)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0366 | 0.0370 | 0.0370 | 0.0365 |
| | (0.0249) | (0.0251) | (0.0251) | (0.0243) |
| install=1 | 0.102*** | 0.103*** | 0.103*** | 0.102*** |
| | (0.0267) | (0.0270) | (0.0270) | (0.0266) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1209 | 1207 | 1207 | 1207 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.6: Logit model for the probability of subscribing to the tariff (experiment data, electricity consumption 5% tails excluded)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| video=1 | 0.0377* | 0.0354* | 0.0353* | 0.0313 |
| | (0.0221) | (0.0208) | (0.0207) | (0.0193) |
| install=1 | 0.0641** | 0.0607** | 0.0607** | 0.0562** |
| | (0.0258) | (0.0250) | (0.0251) | (0.0250) |
| Charging station | No | Yes | Yes | Yes |
| Mean electricity consumption | No | No | Yes | Yes |
| Municipality controls | No | No | No | Yes |
| Observations | 1209 | 1207 | 1207 | 1207 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

# Appendix C. Brochures, letters and video

Figure Appendix C.1: Brochure for the control group (front and back)

Figure Appendix C.2: Brochure for the video treatment group (front and back)

Figure Appendix C.3: Brochure for the installation-cost treatment group (front and back)

Table C.1: Transcript of the video

**Slide 1**: (Pot with money full screen, bottom right logo): Want to save up to 500 francs over 5 years?
**Slide 2**: (Heat pump with electric car, full screen, bottom right logo): If you have an electric car charging station or a heat pump you can subscribe to our Flexibility Tariff.
**Slide 3**: (Girl stretching all screen, bottom right logo): How does the Flexibility Tariff work?
**Slide 4**: (Artificial intelligence image, full screen, bottom right logo): Through artificial intelligence-based systems, [Company XY] remotely and dynamically manages the operation of your appliances throughout the day, without compromising your comfort in any way. Appliances can be blocked, or their power reduced, for short periods of one or maximum two hours.
**Slide 5**: (All-screen discount, bottom right logo): Meanwhile, you benefit from a 1 cents/kWh discount on the daytime rate...
**Slide 6**: (Pylons all-screen, with appliances icons appearing when it says "during high consumption times," logo on the bottom right): ...and you will also allow for greater stability of the electrical grid, preventing overloading during high consumption times (appliance icons) and ensuring more efficient grid management.
**Slide 7**: (Electrical panel, full screen, with logo on the bottom right) To receive this discount, all you need is for [Company XY] to install a remote control in your home's main electrical panel that will allow us to control your appliances. You will be required to lay the control cable. The average price for laying the control cable is 300 francs, and may vary depending on the characteristics of your home.
**Slide 8**: (E-mail with keyboard, full screen, with logo at bottom right): For more information send an email to [email censored] by June 30 including your full name, your address, your customer number (found on your [Company XY] invoice), and indicate what equipment you own between charging columns or heat pumps (or both).
**Slide 9**: conclusion with logo.

*Notes:* Images shown are described in parenthesis. The local energy provider is renamed as "Company XY".

Table C.2: Accompanying letter for clients in the control and video treatment groups

| |
|---|
| **Flexibility Tariff: More flexibility, more savings**<br><br>Dear Customer,<br><br>We are pleased to inform you that we have introduced a more advantageous tariff for those who own heat pumps or charging stations for electric cars (> 3 kW). By subscribing to the Flexibility Tariff, you will have an immediate saving of 1 cts/kWh on the grid component of the daytime tariff. Depending on your consumption, **the savings can be up to CHF 500 over 5 years**. In order to subscribe to this tariff, a control cable must be installed by an electrician.<br>If you are interested in the Flexibility Tariff, please write to [email] stating your first name, last name, address and [Company XY] customer number (found here above).<br>**This tariff proposal is valid until June 30, 2023.**<br><br>With our best regards.<br>Company XY |

*Notes:* The local energy provider is renamed as "Company XY", whose email address has been censored. Bold sections reflect the format in the original letter.

Table C.3: Accompanying letter for clients in the installation treatment group

**Flexibility Tariff: More flexibility, more savings**

Dear Customer,

We are pleased to inform you that we have introduced a more advantageous tariff for those who own heat pumps or charging stations for electric cars (> 3 kW). By subscribing to the Flexibility Tariff, you will have an immediate saving of 1 cts/kWh on the grid component of the daytime tariff. Depending on your consumption, **the savings can be up to CHF 500 over 5 years**. In order to subscribe to this tariff, a control cable must be installed by an electrician.
The proposal is even more advantageous for you, as the installation of the control cable and **related costs are borne by our company**. If you are interested in the Flexibility Tariff, please write to [email] stating your first name, last name, address and [Company XY] customer number (found here above).
**This tariff proposal is valid until June 30, 2023.**

With our best regards.
Company XY

*Notes:* The local energy provider is renamed as "Company XY", whose email address has been censored. Bold sections reflect the format in the original letter.

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