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ABSTRACT

Which Households Respond to Electricity Peak Pricing amid High Levels of Electrification?*

We examine heterogeneity in Norwegian households' price responses to critical peak pricing (CPP) on electricity consumption, using a large-scale randomized controlled trial (RCT), high-frequency electricity data, and default enrollment. Increasing the grid transmission charge by 4,067% (corresponding to an increase in the electricity price by 1,242%) leads to a 12.5% reduction in consumption, and virtually eliminates the consumption "peak". In contrast to prior studies from less electrified countries, the effect is broad-based, and similar across income groups. These findings provide a unique lens into the effectiveness of demand-based policies, and their impact across household groups, in a more electrified future.

JEL Classification: C93, D12, L94, Q41

Keywords: critical peak pricing, grid transmission charge, peak demand, household heterogeneity, RCT, default enrollment, electrification

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1 Introduction

To which extent will residential electricity demand respond to prices, and which households will respond, once homes become fully electrified? As power from intermittent sources, such as wind and solar, grows as a share of the electricity mix, the ability to manage demand through market mechanisms can help avoid blackouts. Such policies may also reduce peak demand and transmission constraints and thereby reduce the need for costly investments in grid expansion and generation capacity.

However, in practice, the effectiveness of demand-side management policies to match household demand to temporary reductions in electricity supply and transmission constraints hinges on demand being sufficiently price-elastic. Forecasting the price sensitivity of demand in the near future is difficult because the level of electrification is bound to increase,[1] and we cannot necessarily infer future demand elasticity from current estimates obtained in contexts with low levels of electrification. In other words, as the demand shifts outward, the shape of the demand curve will likely change as well. Therefore, to be able to assess whether demand peaks can be managed with critical peak pricing, utilities and regulators need estimates of the price response of electricity consumption in a setting with high levels of electrification.[2] Furthermore, even if peak pricing is an effective tool to manage demand, equity concerns may prevent it from being a desirable policy, thus research on the sensitivity of electricity demand across income groups is needed. More generally, understanding households' price response heterogeneity is crucial for improving the design and acceptability of demand-side policies.

To answer these questions, we conduct a large-scale RCT in a highly electrified country in which income data is readily available. Specifically, we estimate Norwegian households' demand response to critical peak pricing (CPP) on residential electricity consumption. Norway is highly electrified and has one of the world's highest levels of per capita electricity

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[1] Policies promoting electrification and the transition out of fossil fuels will lead to considerable increases in electricity demand and greater dependence of our homes on electricity (European Commission, 2019; White House, 2021a,b).

[2] For example, only 39% of US households were using electricity as their main heating source in 2019 (IEA, 2020). In Norway, virtually all households use electricity as their main heating source. (Oil and paraffin furnaces were phased out nation-wide in 2020. There is little infrastructure for natural gas distribution to homes. As a result, heating or home appliances that use natural gas are not common.)

consumption (23.5 MWh in 2019, compared with 12.8 MWh in the United States and 6.0 MWh in the EU (IEA, 2019)). Heating and most appliances rely on electricity, including water heaters, dryers, stoves and ovens. It further has a high penetration of electric vehicles, amounting to 43% of new sales and 9% of the existing registered fleet in 2019 (Norwegian Goverment, 2019). As such, understanding the extent to which households are willing to reduce electricity consumption in response to a price increase in Norway may inform the extent to which demand-side policies can be employed effectively in the U.S. in an increasingly electrified future. Our data also allow us to examine heterogeneity in households' price responses, and in particular, compare effects across income groups to address important equity concerns.[3]

We implement the price increase as a temporarily increased grid transmission charge, which is a component of the total price for electricity facing households. We increase the transmission charge by 4,067% in a certain time window on selected days, which leads to an average overall price increase of 1,242%. We have access to hourly electricity consumption data for about 22,000 households, along with household characteristics, which allow us to study effects across subsets of the sample. Consumers are enrolled by default in the RCT, with an opt-out option. This design feature greatly reduces sample selection concerns and thus improves external validity.[4] We implement the CPP events on nine selected cold-weather days between December 2019 and April 2020 during peak demand hours, which are in the late afternoons and early evenings (4PM-10PM). Aside from constituting the treatment, CPP is

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[3] Reiss and White (2005) find that, although low-income households in California tend to be more price sensitive than high-income households, income effects manifest primarily through households' choice of appliances. We do not know, however, how high-income households would behave if given electrical appliances. Ito et al. (2018) suggest that in Japan high-income households respond less to peak pricing than low-income households. (Japan's per capita electricity consumption was half that of the U.S. with 7.9 MWh in 2019 (IEA, 2019).) One may not want to extrapolate equity concerns from previous studies as the income effect may change with higher levels of electrification.

[4] Opt-in recruitment typically attracts customers who display greater interest in their electricity consumption and pay more attention to prices than non-recruited customers (Joskow and Wolfram, 2012; Harding and Sexton, 2017). Studying the question of how demand responds to peak pricing in a setting with much lower levels of electrification, Fowlie et al. (2021) is the only other study implementing a default enrollment design with opt-out. They estimate that the customers who do not opt in reduce peak consumption during peak events by only half relative to the customers who actively opt in. Similarly, by using a censored selection model accounting for full population participation based on observables, Andersen et al. (2019) find that demand response estimates obtained in the context of opt-in studies should be revised downwards by up to a factor of four to correct for the sample selection bias. These findings illustrate the importance of our design choice.

also a relevant policy intervention in Norway because the existing grid transmission charge is set to either a winter or summer rate and ignores time-varying congestion on the grid. In our experiment, CPP events are announced by text messages on the day prior to each event.

The intention-to-treat (ITT) estimates show a 12.5% reduction in electricity consumption in the treatment group relative to the control group during CPP hours. This reduction in demand almost entirely removes the "peak" demand, which amounts to about 14.5%. (14.6% of the subjects opt out from the default enrollment scheme and behave similarly to the controls. The local average treatment effect (LATE) that excludes such non-compliers is 14.2%, comparable to the ITT estimate.) Households with electric vehicles reduce electricity consumption by a further 5.3% in response to CPP, almost flattening out their electric vehicle-specific "peak" demand of 6.1%. Households' percentage-reduction in electricity is similar across (pre-treatment) consumption levels and across block-level income groups. In sum, we find that households respond strongly to peak pricing, so as to remove the demand "peak", even in a setting with high levels of electrification. Furthermore, they do so quite homogeneously across income groups.

We present additional findings that are interesting in their own right, but also illustrate why the answer to the question how peak pricing affects demand *in a setting with high electrification* cannot necessarily be inferred from existing research. For example, our findings of broad-based reductions in demand differ from those documented in Reiss and White (2005), where reduction is limited to the small share of households who use electricity for space heating or air conditioning. Our effect is also not mostly driven by high-users as found in Ito et al. (2018) and Burkhardt et al. (2019). Peak demand reduction also does not rely on households having installed an In-Home-Display (IHD) device providing real-time price and consumption information, in contrast with findings in Jessoe and Rapson (2014) – although we do find that the response is about one-third stronger when households have IHD technology installed. In addition, we find that households without electric vehicles respond to CPP events on cold days with net reductions in electricity consumption and without increases in demand outside the intervention hours, differing from the load shifting behavior observed in Bollinger and Hartmann (2015). Nevertheless, we find some load shifting to shoulder hours for electric vehicle households, consistent with findings in Burkhardt et al.

(2019). Similar to Jessoe and Rapson (2014), we also find evidence of habit formation, suggesting that the previous finding has external validity, and that households in the U.S. and Norway show similar behavior across at least some dimensions.

At a conceptual level, our findings complement the existing literature in three ways. First, they show the extent to which demand-side management policies can be effective once homes become fully electrified – including heating, home appliances, and electric vehicle charging. Furthermore, we show that with an extreme price increase all household groups respond to CPP notifications, and to such extent that the "peak" of the demand is almost completely eliminated.

Second, this paper contributes to the existing time-varying pricing experiments by simplifying some of the usual design features. For example, building on Gillan (2017), who finds evidence of price inattention, our design goes one step further and omits information about the level of the price increase in the CPP notifications. As a result, most consumers likely do not have knowledge of the actual price increase when responding to CPP. (Only the introductory material sent to participants at the beginning of the experiment mentioned that the grid transmission charge was to increase to 10 NOK/kWh during CPP events. Less than a quarter of the respondents in the post-experimental survey could correctly select that value.) Our results suggest that households respond to demand-side management policies without needing exact information on prices. Furthermore, our design does not require consumers to install an IHD to monitor real-time electricity price and consumption, in contrast with many studies (e.g., Ito et al. (2018); Gillan (2017)). We thus show that CPP can be readily implementable as reduction in peak demand does not hinge on the home installation of a costly piece of technology.[5]

Third, it is the first study to examine a time-varying price for electricity transmission along the grid. Indeed, despite time-varying prices having received much attention as a means to reduce peak load demand when electricity generator capacity binds, they have not been empirically examined in the context of peak-load congestion in transmission networks (Wolak,

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[5] The few customers in our sample with IHD prior to the start of the experiment (5%) are randomly assigned among the treatment and control groups. Consumers with IHD reduce peak demand by a further 37% relative to other consumers. This effect is large but considerably smaller than the 150% additional effect documented in Jessoe and Rapson (2014) and 45% average (up to 76%) effect in Bollinger and Hartmann (2015).

2011; Harding and Sexton, 2017). Because of local grid capacity constraints, the marginal costs of electricity delivery to households do not only vary over time but also across regional transmission networks. Therefore, reducing peak demand in a local transmission network close to capacity is considerably more valuable than reducing peak demand in a different transmission network with plenty of spare transmission capacity, all else equal. The value of reducing peak demand will thus depend on location-specific marginal prices that account for local congestion on the grid. In this sense, grid transmission CPP can complement real-time pricing for electricity generation.

The paper is organised as follows. The next section provides background on the Norwegian electricity market. Section 3 presents the study design and data. Section 4 outlays the empirical analysis. Section 5 describes and discusses the results. Last, Section 6 concludes.

2 Background on the Norwegian electricity market

The Norwegian electricity market is deregulated with more than 50 different utilities offering retail electricity contracts to consumers. Grid utilities manage electricity transmission on local networks and have a monopoly over the local grid. The total electricity price that households face consists of a real-time spot price paid to the retailing utility,[6] a grid rent for the grid connection paid to the grid utility, and other small fees levied by the government. As most electricity in Norway is generated from hydro-power plants, the intra-day variations in the spot price are relatively small in the study region (Figure A2). However, seasonal variations can be large depending on the hydrological balance (Figure A3). Customers in Norway typically do not have access to real-time electricity consumption or prices (with the exception of a few small, recent government-sponsored pilot programs), nor do they use automation technologies such as smart chargers for electric vehicles.

The grid transmission charge is set to either a summer tariff or a winter tariff.[7] In the years 2017 and 2018, the summer and winter tariffs were set to 0.1813 NOK/kWh and

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[6] The retailing utility further levies a small fee on top of the spot price. The country is divided into five regional markets, each with its own spot price.

[7] In addition to this grid transmission charge per kWh, the grid rent includes a fixed fee, which is set to 1,000 NOK per year for apartments, or about 111 USD using the November 2020 currency rate, or 2,500 NOK per year for detached or semi-detached houses.

0.2563 NOK/kWh, respectively. The winter tariff, in effect from November 1st to April 30th, is more expensive due to higher heating-related demand and congestion on the transmission networks. Grid utilities are mandated to deliver electricity at all times, thus the total capacity of the grid is determined by local peak demands, i.e., typically in the late afternoons and early evenings on the coldest weekdays in the winter. Yet, as the winter tariff does not vary within the season, customers do not currently receive price signals about grid congestion.

3 Experimental design and data

3.1 Experimental design

The RCT design consists of a single, CPP transmission charge increase with day-ahead notification. Motivations for this design stem from the facts that (1) transmission levels approach grid capacity constraints only on a small number of days at most over the winter, (2) grid congestion can be relatively well predicted based on the temperature forecast a day in advance – and the literature documents that, absent automation technology, day-ahead notifications perform better at triggering a consumer response than day-of notices (Jessoe and Rapson, 2014; Harding and Sexton, 2017), and (3) consumers are often not sensitive to changes in price levels.[8]

To implement the RCT, we partner with the grid utility Ringerikskraft Nett, which serves around 22,000 customers in the municipalities Ringerike and Hole in the Southeast of Norway (one hour drive north of Oslo).[9] At the end of the selection process, our sample consists of 11,476 electricity meters. Using a stratified random sampling design, residential electricity customers were assigned to either the treatment group or the control group. The treatment

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[8] For example, Jessoe and Rapson (2014) find similar responses for price increases from 200% to 600%, as well as Gillan (2017) for price increases ranging from 31% to 1,875%.

[9] To select our customer sample, we keep the registered electricity meters satisfying the following criteria. First, we keep meters with total electricity consumption in 2018 between 2,000 kWh and 50,000 kWh so as to exclude potential businesses or malfunctioning meters. Second, we discard customers who did not provide a mobile phone number to send day-ahead SMS notifications. Third, we require meters to be registered with a single customer and customers to be associated with a single meter to ensure the person receiving the notifications lives at the address where the meter is located. Of the 11,712 pre-selected meters, subsequent data on 190 meters were not provided by the utility, for example due to customers moving. An additional 12 meters with values exceeding 50 kWh for a single hour are also dropped. Finally, a further 34 meters are dropped due to having zero electricity consumption in three consecutive weeks.

group consists of 3,833 customers, while the control group consists of 7,643 customers.[10] Stratification ensured that the two groups were balanced across households with respect to registered electric vehicle(s) and IHD. Non-compliance to the experimental design was observed for 560 customers in the treatment group who opted out and were not subject to peak pricing (14.6%). Figure A1 illustrates the timing of non-compliance in the treatment group – 70% of those 560 customers were non-compliant prior to the first CPP event. Another nine customers from the control group (0.1%) requested to participate in the CPP treatment.[11] These non-compliers are included in the main analysis, where we estimate the intention-to-treat (ITT) effect according to their original assignment.

The CPP treatment raises the winter grid tariff from 0.24 NOK/kWh to 10 NOK/kWh (a 4,067% increase) from 4PM to 10PM on nine CPP weekdays in the period December 2019 to April 2020 (two CPP days per month from December to March and one CPP day in April). CPP weekdays were called by the grid utility a day in advance as informed by high transmission congestion forecasts related to cold temperatures.[12] The CPP program was designed to be revenue-neutral for the grid utility conditional on electricity consumption not changing from the previous year. As a result, the winter grid tariff for non-CPP hours was reduced to 0.05 NOK/kWh in the treatment group.

An overview of the timing of the CPP events and communication with the customers is depicted in Figure C1. On November 25th 2019, customers in the treatment group were mailed a letter describing the overall goal of the CPP program, including the number of CPP events, the CPP hours, and who to contact to opt out. Enclosed to the letter was a two-sided brochure featuring on one side the CPP transmission charge increase to 10 NOK/kWh with

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[10] Our pre-registration plan included a 2×2 design featuring a second treatment arm consisting of an information treatment – without any price change. However, due to the warm 2019-2020 winter forecast and low congestion levels anticipated on the grid, the grid utility decided to cancel this arm of the treatment prior to the start of the RCT. Customers originally assigned to the information treatment arm were pooled with the control group. Because of the warm weather, the grid utility further decided to skip the first CPP event planned for November 2019, resulting in nine events instead of the ten originally planned. The average temperature in the study area during winter 2019-2020 (December through April) was 2.3°C, which is 2.5°C warmer than in winter 2018-2019 and 3.9°C warmer than in winter 2017-2018.

[11] A utility representative gave an interview about the CPP program in the local newspaper, leading to a few customers requesting to participate in the CPP treatment.

[12] By choice, Mondays were never called by the utility due to staffing constraints on Sundays to prepare for a Monday event. In practice, most CPP weekdays happened on Tuesdays and Thursdays, with one Wednesday drawn. No Friday ended up being called.

an example of cost calculation for running an appliance during CPP hours, and conservation tips for electricity use on the other side.[13] Customers in the treatment group received an SMS (between 2PM and 3PM) on the day prior to a peak event, with a second SMS reminder sent on the day of an event for the first five events. The content of the SMS is shown in Appendix C.4. Importantly, the 10 NOK/kWh grid CPP level is not displayed in the SMS; it only appears in the brochure.

3.2 Data

Using Ringerikskraft Nett's high-frequency, smart-meter data on household electricity consumption, we construct our dependent variable as the natural logarithm of hourly electricity consumption in and outside of the CPP treatment window (4PM-10PM). The temperature variable is constructed using the hourly temperature at the Hønefoss weather station and, thus, does not vary across households. We further obtained household income data for the year 2020 at the block-level – referred to as "grunnkrets" in Norway. Grunnkrets encompass relatively small, homogeneous areas – with around 500 people (including kids) or around 200 households in our sample area. Our sample consists of 71 grunnkrets. Mean and median block-level household income in our sample are 689,425 NOK (or 75,285 USD using the November 2020 currency rate) and 618,592 NOK (67,550 USD), respectively.

Our treatment assignment is randomly stratified by electric car ownership and IHD. Using customers' name and address, we match households with the electric vehicle ownership registration database from the Norwegian Public Roads Administration (Vegdirektoratet).[14] Table 1 shows treatment assignment for the 714 electric vehicle records that are matched on full name or last name and address. Last, although every customer in Norway is equipped with a smart meter, the vast majority of households typically do not have IHD installed and

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[13] The letter and brochure are shown in Appendix C.2. On December 6th, customers were emailed a shorter version of the letter they received in the mail, notifying them that the first CPP event would occur the following week, and a reminder on how to opt out (Appendix C.3). The email also included a link to the online brochure that they received in the mail.

[14] As of mid-September 2019, 1,200 inhabitants in the municipalities Ringerike and Hole were registered as the owner of at least one electric vehicle. 611 of these were merged by first and last names to an electricity meter. To include cases where the car and meter are registered to different members in the household, a further 103 were merged by last name and address. Finally, 107 (unique) matches were made using the address only, but we deemed the quality of those matches too uncertain, and do not include them in the analysis.

learn about their electricity consumption via their monthly bill.[15] Overall, a total of 738 customers have received and installed an IHD in our sample – of whom 595 remained at the end of the pre-selection process for the experiment. We randomize those customers, resulting in 201 customers with IHD assigned to the treatment group and 394 to the control group.

Descriptive statistics are shown in Table 1. Electricity consumption and observables potentially influencing electricity consumption and the response to the treatment appear well balanced between the treatment group and control group in the pre-treatment period. The table thus provides support for the randomization of treatment across our sample.

Complementary survey data

The RCT data are supplemented by two surveys administered before and after the CPP intervention. The pre-treatment survey was distributed by the electric utility company between 2017 and summer 2019 to the 1,865 customers who received an IHD (albeit not necessarily installed it). A company employee called (multiple times) every customer for a response rate of 50.1%. Summary statistics are shown in Table A1. The post-experimental survey was conducted in spring and summer 2021 to help interpret the CPP results and learn about the factors driving consumption behavior. All the customers in the treatment group received a link to the survey via SMS in April 2021 and then via email in June 2021 for a response rate of 14.6%. Responses are shown in Table A2.

4 Empirical strategy

First, we provide visual evidence of the effect of the CPP treatment on electricity consumption. Then, we describe the empirical models.

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[15] The most timely electricity consumption is available only up to the previous day by logging onto an app or into a secure government website. However, several small, recent, ongoing government-sponsored grant programs are distributing IHD to examine its effect on consumption. One of these programs involves the customers served by our grid utility (https://www.energipilot.no/). The program randomly made free IHD offers to 2,545 customers in our sample in 2017, with 100 of those accepting the offer and installing the device. Due to low take-up, customers who were not initially randomized also received the device.

4.1 Graphical inspection

Figure 1 depicts the log of electricity consumption for each CPP event, while separating the response of households with electric vehicles from that of households without. Although households with electric vehicles have a higher electricity consumption, the consumption pattern between electric vehicle and non-electric vehicle households is relatively similar across the nine CPP days. Furthermore, the solid and dashed lines for the treatment and control groups, respectively, follow each other closely, except during CPP events during which they diverge sharply.[16]

4.2 Empirical models

The main hypothesis is that CPP decreases peak electricity consumption. Important questions we aim to answer is how household heterogeneity affects treatment response, whether the treatment effect is associated with load shifting to non-peak hours or other days, and whether one can detect habit formation or habituation to the treatment over time.

Our basic model specification is shown in equation (1):

$$\begin{aligned} E_{it} &= \beta_1 Treat_i * Peak_d * Day_d + \gamma_1 Treat_i * NPeak_d * Day_d \\ &+\beta_2 Treat_i * Peak_d * Post_d + \gamma_2 Treat_i * NPeak_d * Post_d \\ &+\delta f(temp)_t + \phi X_{it} + \epsilon_{it}. \end{aligned} \tag{1}$$

The variable E_{it} indicates household i's log of electricity use in kWh in each hour t. Each day d is divided into two time periods: non-peak hours, namely 12AM-4PM and 10PM-12AM ($NPeak_d$), and peak hours 4PM-10PM ($Peak_d$). $Treat_i$ denotes treatment group status (0 or 1). Day_d is a dummy variable that takes the value 1 on days when a CPP event occurs and 0 otherwise. $Post_d$ denotes the two days following a CPP event. The variable *temp*

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[16] Figure A4 offers an overview of electricity consumption over the five months of the experiment. Days with CPP are easily recognizable from the difference in consumption patterns between the treatment and control groups, while no differences between the two groups are noticeable on non-CPP days. (Short, local power outages (e.g., due to trees falling on power lines) took place on January 7th and 14th and February 21st. These outages affected treatment and control groups alike and always occurred outside CPP events.) Furthermore, Figure A5 shows the log of electricity consumption on the nine CPP days, including the day prior and the day after each CPP event. The treatment effect appears concentrated on the six CPP hours on the day of the CPP event, with no evidence of load shifting to non-CPP hours or non-CPP days.

represents hourly temperature in degree Celsius in the town of Hønefoss. Our measure of temperature, $f(temp)_t$, consists of a polynomial of degree three in hourly temperature and linear measures of the average temperature the preceding 24, 48 and 72 hours. The vector $\mathbf{X}_{it}$ includes household fixed effects, time of day fixed effects (peak and non-peak hours) and date fixed effects to control for demand shocks that affect our sample.

Households owning at least one electric vehicle may respond differently to treatment relative to non-electric vehicle households due to a larger electric consumption to start with and greater flexibility regarding when to charge the car. To allow for electric vehicle treatment heterogeneity, we interact all the terms in equation (1), except $\mathbf{X}_{it}$ and $f(temp)_t$, with a dummy variable, $Ecar$, indicating whether the household owns an electric vehicle.

To examine more precisely whether households shift electricity consumption to pre- and post-CPP hours, we refine equation (1) to include shoulder hours.[17] Our preferred specification is depicted in equation (2):

$$\begin{aligned} E_{it} &= \beta_1 Treat_i \times Peak_d \times Day_d + \gamma_1 Treat_i \times NPeak_d \times Day_d \\ &+ \beta_2 Treat_i \times Peak_d \times Post_d + \gamma_2 Treat_i \times NPeak_d \times Post_d \\ &+ \lambda_1 Shld_d + \lambda_2 Treat_i \times Shld_d \times Day_d + \delta f(temp)_t + \phi X_{it} + \epsilon_{it}. \end{aligned} \tag{2}$$

The shoulder hours in each day are defined as the two hours pre- and post-CPP hours, i.e., 2PM-4PM and 10PM-12AM, while the non-peak hours are now redefined as 12AM-2PM. Time of day fixed effects now consist of peak, non-peak, and shoulder hours.

5 Results

5.1 Response to CPP treatment

We show empirically the effect of the grid CPP treatment on household peak electricity consumption in Table 2. (Results without household fixed effects are qualitatively similar and are shown in Table B1). Results for equation (1), either without or with temperature

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[17] Equation (2) originally contained a typo in the pre-registration plan that said that the shoulder hours indicator was to interact with the indicator for the post-CPP days. This should have been the indicator for the CPP day.

controls, are shown in columns (1) and (2), while results for the model allowing for electric vehicle treatment heterogeneity are depicted in column (3). Results for equation (2) with shoulder hours, either without or with electric vehicle treatment heterogeneity, are shown in columns (4) and (5).

For each specification in Table 2, a CPP event is associated with a reduction in peak electricity consumption among treatment households ranging from 0.134 to 0.140 log points (or 12.5% to 13.1%) relative to control households ($Treat \times Peak \times Day$). Strikingly, this intention-to-treat (ITT) estimate smooths out almost exactly peak electricity demand ($Peak$), ranging from 0.138 to 0.161 log points (or 12.9% to 14.9%). In the post-experimental survey, respondents reported lowering indoor temperature (41%), using more firewood for heating (47%), taking shorter showers (47%), and changing their use of appliances (80%) (Table A2).

Given an 86% compliance to the treatment group assignment, we estimate the local average treatment effect (LATE) among the compliers – those who actually faced the CPP scheme. The LATE effect is estimated by using treatment assignment as an instrumental variable for exposure to the CPP, producing an estimate of -0.153 log points, or 14.2%. (The estimation is done including only peak hours and excluding the two days after each CPP event, but otherwise with the same specification as in column (2) in Table 2.)

The spot price varied from 0.14 NOK/kWh to 0.59 NOK/kWh over the nine CPP events (Figure A3). As a result, the total electricity price increase in the treatment group relative to the control group (taking together the grid transmission charge and spot price) ranged from 892% to 1,498%, with mean 1,242%. With a consumption reduction of 12.5% (our preferred specification; column (5)), this gives an average price elasticity of -0.010.[18] This elasticity is to be interpreted with caution because the CPP grid transmission charge level is not displayed in the SMS notification, and households typically do not know the exact spot price. Based on the post-experimental survey, less than two thirds of respondents read the brochure mentioning the level of the grid transmission charge increase, and less than a quarter could correctly select the 10 NOK/kWh level of the CPP for the grid charge (Table

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[18] As discussed in Jessoe and Rapson (2014), who calculate an elasticity of -0.12 for a 200% price increase, we caution against taking this elasticity at face value given the extreme price increase implemented. It is quite plausible in our case that much lower price increases might have induced the same electricity reduction.

A2). Because most consumers likely did not have knowledge of the actual price increase, our results suggest that households respond to demand-side management policies without needing precise information on prices.

Starting with the basic model in equation (1), without or with temperature controls (columns (1) and (2), respectively), estimates indicate a slightly lower electricity consumption during the two days post CPP, in particular during peak hours. There is thus no sign of load shifting to the next days, but rather evidence of a persistent effect on the days following a CPP event. This persistence is consistent with households responding to a CPP event by adjusting the setting of heating thermostats during peak hours and not returning the thermostat to the pre-CPP event setting for some days. This interpretation is consistent with 21% of respondents in the post-experimental survey reporting reprogramming their thermostat for the CPP event (Table A2).

Electric vehicle treatment heterogeneity is shown in column (3). Households with electric vehicles display higher electricity consumption during peak hours than non-electric vehicle households ($Peak \times Ecar$ of 0.059 log points or 5.7%; p-value<0.01). Remarkably, the treatment smooths out completely the peak consumption that is specific to electric vehicle households ($Treat \times Peak \times Day \times Ecar$ of 0.054 log points or 5.3%; p-value<0.05). Electric vehicle households substantially shift their consumption to non-peak hours both on the CPP day and on the two post-CPP days ($Treat \times NPeak \times Day \times Ecar$ and $Treat \times NPeak \times Post \times Ecar$). Consistent with this result, we find that two thirds of the respondents in the post-experimental survey who are registered as electric vehicle owners in our sample report changing their charging time.

Results for equation (2) with load shifting to shoulder hours are shown in columns (4) and (5), either without or with electric vehicle heterogeneity, respectively. Results in column (4) suggest that the reduction in electricity consumption outside the peak hours of a CPP day largely took place in the shoulder hours, with a reduction of 0.038 log points or 3.7% for the treatment group relative to the control group. The reduction in electricity consumption in the shoulder hours is not significantly different when examining the response of electric vehicle households ($Treat \times Shld \times Day \times Ecar$; column (5)).

To examine more precisely how CPP affects the behavior of the treatment group relative to the control group throughout the day, we show the effect of CPP on household electricity consumption for each hour of a CPP day in Figure 2. In addition to the sharp peak demand reduction observed during the CPP hours, 4PM-10PM, reductions in demand are already noticeable from 9AM on and last until 11PM, possibly capturing the effect of households manually adjusting indoor temperature thermostats before leaving for work. The reduction steadily increases throughout the early afternoon hours, up to the start of the CPP event. In addition, we observe a small increase in consumption during the early morning hours of a CPP day, from 5AM until 8AM, indicating a small amount of load shifting, consistent with the sign of $Treat \times NPeak \times Day$ in Table 2, column (5), which separates shoulder hours from other non-peak hours. However, the net overall effect during the day, i.e., encompassing non-peak and shoulder hours, remains negative ($Treat \times NPeak \times Day$ in Table 2; column (3)). The overall pattern is similar for households with an electric vehicle, with the difference that estimates are substantially larger. This is reasonable because these households have a considerably higher electricity consumption to manage.

5.2 Response to CPP treatment across household groups

To better understand how different households respond differently to the treatment, we now estimate equation (2) (with household fixed effects and allowing for electric vehicle heterogeneity) for different subsamples. Results are shown in Table 3 for households belonging to different block-level income quartile and in Table 4 for households with or without IHD, and for household groups defined by their electricity consumption quartile in the pre-treatment period.

In Table 3, we investigate the effect of CPP events on electricity consumption for each household block-level income quartile. The estimates, ranging from -0.124 to -0.139 log points, or -11.7% to -13.0%, are not statistically different from each other.[19] These results contrasts with findings from studies conducted in settings with lower levels of electrification. Using the self-reported income for 588 households in Japan, Ito et al. (2018) find that higher income households are less price sensitive than lower income households. Using data from

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[19] Estimating equation (2) with income heterogeneity, by interacting the variables of interest with the block-level income variable, produces qualitatively similar results.

the 1993 and 1997 waves of the Residential Energy Consumption Survey (RECS) for 1,307 California households, Reiss and White (2005) also find that higher income households are slightly less price sensitive than lower income households, although the difference becomes insignificant once controlling for appliance choice. In our context with high levels of electrification, income does not appear to affect households' responsiveness to peak pricing, thereby, alleviating concerns about the redistributional effects of such schemes.

Table 4 shows that all households, independently of their consumption level and of whether they have an IHD installed, reduce electricity consumption during CPP events. The effect ranges from -0.106 to -0.181 log points or -10.1% to -16.6%. This finding is relevant to policymakers and contrasts with results from prior studies that suggest that peak pricing without access to real-time price and consumption information has a considerably weaker effect (Jessoe and Rapson, 2014), or that most of the response comes from high-use households (e.g., Reiss and White (2005)). In addition, we do not find strong evidence that electric vehicle households in any of the groups considered drive the response to treatment, which is in contrast with findings in Burkhardt et al. (2019). Furthermore, rather than shifting their electricity demand to shoulder hours or onto the next two days, most groups have a tendency to also reduce their electricity consumption, in particular during shoulder hours and the peak hours of the next two days. Responses from the post-experimental survey suggest that some households adjust the setting of programmable and non-programmable thermostats and water heaters, with some inertia for returning to the original setting.

Columns (1) and (2) in Table 4 illustrate the effect of CPP events on consumption conditional on whether households had installed an IHD prior to the RCT to monitor their real-time consumption. Notably, households with IHD have a higher electricity consumption on average ($y_{mean} =$ 0.896 or 2.45 kWh) compared with households without IHD ($y_{mean} =$ 0.569 or 1.77 kWh). Households with IHD display a reduction in consumption of 0.181 log points or 16.6%, compared to 0.132 log points or 12.4% for the group without IHD – amounting to a 37% difference. When households with IHD also own electric vehicles, they dramatically reduce their consumption during CPP events, i.e., by another 0.142 log points or 13.2% ($T \times P \times Day \times Ecar$; p-value<0.05). This is an important finding when considering that electrification will likely be associated with more electric vehicles and smart technologies.

Columns (3) to (6) in Table 4 show the effect of CPP events on consumption conditional on households' pre-treatment electricity consumption. Households in the two lowest consumption quartiles reduce electricity use by 0.106 to 0.119 log points, or 10.1% to 11.2%, in response to the treatment, which is slightly less in relative terms compared to the 0.146 to 0.166 log points, or 13.6% to 15.3%, for households in the top two quartiles.[20] This is another important result for electrification since it implies that CPP is more valuable in absolute terms as electricity consumption grows. This is because the same, or slightly higher, percentage effect of CPP applies to a larger base of electricity consumption.

5.3 Habit formation and habituation to CPP

To examine habit formation, we define *AllPostDays* as any day after the first CPP event, while dropping subsequent CPP days. Table 5 suggests evidence of habit formation as households in the treatment group adjust their consumption downwards also outside intervention days, both during and outside peak hours (by 2.4% and 1.8%, respectively). (Results without electric vehicle treatment heterogeneity are quantitatively similar.) This result supports the conclusions of Jessoe and Rapson (2014), which are derived in a context with much lower levels of electrification. It also provides external validity for their finding obtained from an opt-in sample of households in Connecticut. In addition, we do not find that habit formation differs across households with or without electric vehicles, possibly due to the absence of smart charging technology in Norway.

In Table B3, we examine whether households become habituated to CPP events and, thus, less responsive over time. With the exception of the last CPP event (-0.040 log points or -3.9%), on a warm spring day on April 28th 2020 (Figure A3), we do not find evidence of such trend with responses during CPP events ranging from -0.131 to -0.165 log points, or -12.3% to -15.2%. The absence of a declining treatment response in the event by event analysis suggests that such CPP interventions could be relevant for long-term grid transmission congestion and

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[20] Because the share of electric vehicle households can vary across consumption quartiles, we show in Table B2 the effect of CPP by household consumption quartile separately for electric vehicle households and non-electric vehicle households. For every pre-treatment consumption quartiles, electric vehicle households always respond more to CPP than their counterparts without electric vehicle.

peak demand management.

The last two CPP events coincide with the Norwegian Covid-19 lockdown, which started on March 12th 2020 and lasted, in its strictest form, until April 28th 2020. Schools and gyms were closed, work from home was mandated whenever possible, and strict restrictions on social gatherings and social life were implemented. Date fixed effects control for the component of the shock that affects all households. Yet, it is possible that response to treatment during the lockdown changed in ways not captured by the date fixed effects. Three quarters of the respondents in the post-experimental survey stated that Covid restrictions did not affect their behavior, while 14% said it made it harder to respond to CPP events (Table A2). Results in Table 2 are qualitatively similar when excluding the last two CPP events from the analysis. In addition, column (8) in Table B3, shows that the March 31st 2020 event remains associated with a 14.4% reduction in peak demand, which is similar to the response to CPP events prior to the lockdown.

5.4 Effect on households' electricity bill

The CPP program is designed to be ex ante revenue neutral for the utility, assuming no change in electricity consumption. It is achieved by lowering the grid transmission charge from 0.24 NOK/kWh to 0.05 NOK/kWh outside the CPP events in the treatment group. As a result, if the average customer in the treatment group maintained her consumption as in the previous year (i.e., 0-price elasticity), she would pay the same bill whether facing the treatment or control group pricing. As Joskow and Wolfram (2012) point out, one of the main barriers to the adoption of time-varying pricing is the fear of large redistributions across households, in particular at the expense of poorer households. Despite the ex ante revenue-neutrality of our CPP scheme, equity concerns could arise if a small number of households are were responsive and captured most of the benefits from the program, for example because they own electric vehicles and have more-elastic demands.

By observing electricity consumption in the treatment group during the experiment, we can compare the actual bill of these households with their counterfactual bill had they received the control pricing, holding their new consumption pattern constant. Table 6 shows the difference and percentage difference between the actual and counterfactual bills for the mean and different percentiles of households in the treatment group. (For the full distribution, see Figure B1.)

In Table 6, the average household in the treatment group saves an average of 52 NOK per month (or 5.8 USD using the November 2020 currency rate) over the five months of the experiment, which represents 3.9% of her average monthly bill. The mean monthly consumption in the treatment group is 1,783 kWh and amounts to 1,318 NOK. Examining the distribution of households indicates that over 80% of households are better off with the CPP program than with the control pricing. The top 1% saves over 315 NOK on average per month (20.8% of their bill), while the bottom 1% loses over 75 NOK (7.5% of their bill). Nevertheless, only about a quarter of the post-experimental survey respondents thought they saved money under CPP relative to the control pricing, with another quarter thinking they broke even, and 37% reporting not knowing (Table A2).

To investigate the distributional effect of the CPP scheme on household groups, we divide our treated households into four quartiles, denoted q1-q4, based on the average monthly difference between their actual bill under the CPP program and the counterfactual bill under control pricing. (The corresponding average bill difference in each quartile is also depicted in NOK in Table 7.) Columns (1) - (13) in Table 7 illustrate the distribution of attributes of interest across the four quartiles. Households in the lowest consumption quartile (column (1)) are more likely to belong to the top bill difference quartile (q4) – 43% of households in Q1 pay on average 14 NOK more per month, while 48% of households in the highest consumption quartile (column (4)) save an average of 144 NOK/month.

Households with electric vehicles (column (5)) are more likely to be found in the bottom quartile (saving an average of 144 NOK/month) and in the top quartile (losing an average of 14 NOK/month). Households with electric vehicles are high-electricity users – with more scope for adjustment. Indeed, the correlation between having an electric vehicle and belonging to the highest consumption quartile in the pre-treatment period (Q4) is 0.3, while it declines monotonically to -0.1 for the lowest consumption quartile (Q1). Households with IHD (column (6)) are unambiguously better off under the new CPP program.

Using average household income at the block-level shows a relatively even distribution of winners and losers across income quartiles, in particular in the middle of the income distribution (columns (8)-(9)).[21] There are however small, noteworthy differences for households in the lowest (column (7)) and highest income quartiles (column (10)). Households in the highest income quartile (Q4) are more likely to be better off under the CPP scheme than households in the lowest income quartile, who are more likely to be in the top bill difference quartile.

Drawing from a survey of the households who received an IHD prior to the start of the CPP program, households with larger homes (above 150m^2 or 1,615 sqft) or who can use wood as an alternative heating source are more likely to benefit from the CPP program (columns (11)-(13)).

6 Conclusions

This paper examines the extent to which peak pricing can be effective at curbing residential electricity demand once homes become fully electrified. Policies promoting the electrification of residential buildings and of the vehicle fleet are being discussed in many countries. In the U.S., it will translate into the adoption of electricity as the main heating source for the majority of households – and the switch to ever more home appliances connected to the grid. The implications of such new consumption patterns and habits on the responsiveness of households to demand-side management policies are difficult to forecast.

Our RCT provides insights into how households in another, highly electrified country may behave. Given an extreme price increase, we find that all household groups respond to peak pricing, and to the extent that the "peak" of the demand is almost entirely flattened out. It is questionable whether higher price increases could reduce consumption further and it is plausible that we have reached the limit of households' price sensitivity, at least in the short-term. Our findings suggest that high levels of electrification may provide more flexibility for households to respond to CPP by offering key margins of adjustment for all households – reducing the indoor thermostat and changing the use of home appliances. In particular, lowering the indoor temperature in the winter appears to be an effective means to

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[21] Mean quartile block-level household income: Q1: 479,380 NOK, Q2: 588,093 NOK, Q3: 664,511 NOK, and Q4: 997,232 NOK.

response to CPP. This result confirms findings from previous studies in less electrified settings that show that heating or cooling-related electricity demand makes for a large part of the response to demand-side management policies. However, in less electrified countries, like the U.S. today, households' choice of energy source for heating/cooling and home appliances is endogenous. It is thus not obvious ex ante that all households would respond to CPP once all homes become fully electrified. Our findings help addresses the question and suggest that all households would change their behavior. In addition, because households across the income distribution respond to CPP events similarly, the equity concerns of such programs are alleviated. Fully electrifying homes also comes with higher electricity bills, which may make electricity prices more salient and provide incentives to respond to CPP across all income groups.

Furthermore, because our study features a default enrollment design, our estimates are likely representative of the broader population as sample selection bias into the experiment is minimal.

Another novel feature of our study is that CPP notifications do not mention the level of the CPP price increase. Therefore, it is likely that most households do not know the actual price increase when responding to a CPP event. Our results suggest that households respond to demand-side management policies even without needing information on the exact price increase. This finding may help simply CPP notifications, although more research is needed.

This is also the first study examining peak pricing to address grid transmission congestion. As the retail electricity spot price already reflects the real marginal cost of electricity generation, the pricing of local grid transmission congestion stands as the remaining major cause of pricing inefficiency in Norway.

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Table 1 Descriptive statistics for the estimation sample in the pre-treatment period (January 1 – November 30 2019), except otherwise noted.

	Treatment		Control	
	Mean	SD	Mean	SD
Electricity consumption (kWh)	1.81	(1.54)	1.81	(1.53)
12AM-4PM	1.73	(1.47)	1.72	(1.47)
4PM-10PM	2.02	(1.67)	2.02	(1.67)
10PM-12AM	1.88	(1.57)	1.88	(1.56)
Electricity consumption (kWh) (Jan-Mar 2019)	2.68	(1.76)	2.67	(1.76)
12AM-4PM	2.59	(1.69)	2.58	(1.69)
4PM-10PM	2.92	(1.90)	2.92	(1.90)
10PM-12AM	2.70	(1.79)	2.69	(1.77)
Electric vehicle household (0/1)	0.06	(0.25)	0.06	(0.24)
Real-time IHD (0/1)	0.05	(0.22)	0.05	(0.22)
Temperature (°C)	6.86	(8.52)	6.86	(8.52)
Block-level household income (NOK) (2020)	689,691	(291,974)	689,291	(291,338)
Non-complier (0/1)	0.146	(0.35)	0.001	(0.03)
N	3,833		7,643	

Table 2 Effect of CPP events on log of hourly electricity consumption. (1) and (2): Equation (1) either without or with temperature controls. (3): Equation (1) with electric vehicle treatment heterogeneity. (4) and (5): Equation (2) either without or with electric vehicle treatment heterogeneity. All specifications include household, date, and time of day (peak and non-peak) fixed effects. In columns (4) and (5), time of day fixed effects consist of peak, non-peak, and shoulder. (The mean log electricity consumption (*ymean*) is 0.586.)

	(1)	(2)	(3)	(4)	(5)
$Treat \times Peak \times Day$	-0.140***	-0.138***	-0.135***	-0.137***	-0.134***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$Treat \times NPeak \times Day$	-0.002	-0.003	-0.004**	0.005**	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Treat \times Peak \times Post$	-0.020***	-0.015***	-0.014***	-0.015***	-0.014***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Treat \times NPeak \times Post$	-0.005*	-0.006***	-0.007***	-0.006***	-0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Peak$	0.138***	0.143***	0.140***	0.161***	0.157***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
$Treat \times Peak \times Day \times Ecar$			-0.054**		-0.054**
			(0.022)		(0.022)
$Treat \times NPeak \times Day \times Ecar$			0.024***		0.023***
			(0.007)		(0.008)
$Treat \times Peak \times Post \times Ecar$			-0.014*		-0.014*
			(0.008)		(0.008)
$Treat \times NPeak \times Post \times Ecar$			0.017***		0.017***
			(0.005)		(0.005)
$Peak \times Ecar$			0.059***		0.063***
			(0.006)		(0.007)
$Treat \times Shld \times Day$				-0.038***	-0.038***
				(0.003)	(0.003)
$Shld$				0.066***	0.064***
				(0.001)	(0.001)
$Treat \times Shld \times Day \times Ecar$					0.004
					(0.011)
$Shld \times Ecar$					0.017***
					(0.005)
temp	No	Yes	Yes	Yes	Yes
R^2	0.726	0.727	0.727	0.728	0.728
N	41,443,269	41,443,269	41,443,269	41,443,269	41,443,269

Note: Peak: 4PM-10P. Robust clustered standard errors at the household level in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 3 Effect of CPP on log of hourly electricity consumption by block-level household income quartile. All specifications use equation (2) with electric vehicle treatment heterogeneity. All specifications include household, date, and time of day (peak, non-peak, and shoulder) fixed effects.

	Block-level income quartile			
	1^{st}	2^{nd}	3^{rd}	4^{th}
	(1)	(2)	(3)	(4)
$T \times P \times Day$	-0.124***	-0.139***	-0.131***	-0.138***
	(0.011)	(0.008)	(0.009)	(0.010)
$T \times NP \times Day$	0.002	0.003	0.006	0.005
	(0.006)	(0.004)	(0.004)	(0.004)
$T \times P \times Post$	-0.014**	-0.015***	-0.016***	-0.014***
	(0.006)	(0.004)	(0.004)	(0.004)
$T \times NP \times Post$	-0.015***	-0.007**	-0.008***	-0.004
	(0.004)	(0.003)	(0.003)	(0.003)
$Peak$	0.196***	0.147***	0.138***	0.151***
	(0.005)	(0.003)	(0.003)	(0.003)
$T \times P \times Day \times Ecar$	-0.058	-0.106*	-0.082	-0.030
	(0.054)	(0.060)	(0.051)	(0.031)
$T \times NP \times Day \times Ecar$	0.005	0.000	0.003	0.035***
	(0.027)	(0.015)	(0.014)	(0.012)
$T \times P \times Post \times Ecar$	-0.047*	0.005	0.013	-0.031**
	(0.025)	(0.016)	(0.019)	(0.012)
$T \times NP \times Post \times Ecar$	0.032**	0.012	0.007	0.016**
	(0.016)	(0.012)	(0.009)	(0.008)
$P \times Ecar$	0.022	0.051***	0.072***	0.087***
	(0.028)	(0.014)	(0.013)	(0.011)
$T \times Shld \times Day$	-0.036***	-0.043***	-0.035***	-0.038***
	(0.007)	(0.005)	(0.005)	(0.005)
$Shld$	0.099***	0.058***	0.054***	0.051***
	(0.003)	(0.002)	(0.002)	(0.002)
$T \times Shld \times Day \times Ecar$	0.014	0.061**	-0.007	-0.009
	(0.043)	(0.028)	(0.021)	(0.016)
$Shld \times Ecar$	-0.013	0.018*	0.035***	0.031***
	(0.018)	(0.011)	(0.009)	(0.008)
$temp$	Yes	Yes	Yes	Yes
$ymean$	0.236	0.548	0.707	0.797
R^2	0.738	0.705	0.679	0.700
N	8,743,606	12,391,896	9,521,268	11,077,093

Note: Peak: 4PM-10PM. Robust clustered standard errors at the household level in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 4 Effect of CPP on log of hourly electricity consumption for consumer groups based on real-time IHD adoption (columns (1) and (2)), and on pre-treatment electricity consumption quartiles (columns (3) - (6)). All specifications use equation (2) with electric vehicle treatment heterogeneity. All specifications include household, date, and time of day (peak, non-peak, and shoulder) fixed effects.

	IHD		Consumption quartile			
	With	Without	1^{st}	2^{nd}	3^{rd}	4^{th}
	(1)	(2)	(3)	(4)	(5)	(6)
$T \times P \times Day$	-0.181***	-0.132***	-0.106***	-0.119***	-0.166***	-0.146***
	(0.023)	(0.005)	(0.009)	(0.008)	(0.010)	(0.010)
$T \times NP \times Day$	0.003	0.004*	0.006	0.005	0.005*	0.001
	(0.008)	(0.002)	(0.006)	(0.004)	(0.003)	(0.003)
$T \times P \times Post$	-0.010	-0.016***	-0.012**	-0.004	-0.023***	-0.016***
	(0.009)	(0.002)	(0.006)	(0.004)	(0.003)	(0.003)
$T \times NP \times Post$	-0.003	-0.008***	-0.008*	-0.007**	-0.008***	-0.005**
	(0.007)	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)
P	0.162***	0.157***	0.226***	0.132***	0.134***	0.131***
	(0.006)	(0.002)	(0.005)	(0.003)	(0.003)	(0.002)
$T \times P \times Day \times Ecar$	-0.142**	-0.036	-0.069	-0.061	-0.012	-0.051
	(0.068)	(0.023)	(0.048)	(0.055)	(0.040)	(0.032)
$T \times NP \times Day \times Ecar$	0.020	0.22**	-0.046	0.013	0.033**	0.019*
	(0.018)	(0.009)	(0.040)	(0.018)	(0.015)	(0.010)
$T \times P \times Post \times Ecar$	-0.023	-0.013	-0.124***	-0.060**	0.016	-0.003
	(0.025)	(0.009)	(0.034)	(0.028)	(0.018)	(0.010)
$T \times NP \times Post \times Ecar$	0.018	0.019***	-0.028	0.016	0.026**	0.012**
	(0.013)	(0.006)	(0.033)	(0.014)	(0.011)	(0.006)
$P \times Ecar$	0.040**	0.066***	0.143***	0.099***	0.098***	0.068***
	(0.018)	(0.008)	(0.038)	(0.021)	(0.014)	(0.008)
$T \times Shld \times Day$	-0.033***	-0.039***	-0.034***	-0.036***	-0.046***	-0.037***
	(0.011)	(0.003)	(0.007)	(0.005)	(0.004)	(0.004)
$Shld$	0.052***	0.065***	0.110***	0.050***	0.047***	0.047***
	(0.005)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)
$T \times Shld \times Day \times Ecar$	-0.026	0.007	-0.032	0.002	0.016	0.010
	(0.034)	(0.012)	(0.062)	(0.032)	(0.028)	(0.013)
$Shld \times Ecar$	0.017	0.019***	0.068***	0.063***	0.031***	0.022***
	(0.014)	(0.006)	(0.025)	(0.015)	(0.010)	(0.006)
temp	Yes	Yes	Yes	Yes	Yes	Yes
ymean	0.896	0.568	-0.323	0.507	0.876	1.304
R^2	0.615	0.726	0.541	0.323	0.347	0.445
N	2,190,913	39,611,792	10,426,523	10,445,514	10,446,904	10,448,538

Note: Peak: 4PM-10PM. Robust clustered standard errors at the household level in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 5 Habit formation effect of CPP on log of hourly electricity consumption on all non-CPP days past the first CPP day. All specifications use equation (2) with electric vehicle treatment heterogeneity. All specifications include household, date, and time of day (peak, non-peak, and shoulder) fixed effects.

$Treat \times Peak \times Day$	-0.165***
	(0.007)
$Treat \times NPeak \times Day$	-0.009**
	(0.004)
$Treat \times Peak \times AllPostDays$	-0.024***
	(0.006)
$Treat \times NPeak \times AllPostDays$	-0.018***
	(0.005)
$Peak$	0.158***
	(0.002)
$Treat \times Peak \times Day \times Ecar$	-0.090***
	(0.032)
$Treat \times NPeak \times Day \times Ecar$	0.003
	(0.015)
$Treat \times Peak \times AllPostDays \times Ecar$	0.004
	(0.014)
$Treat \times NPeak \times AllPostDays \times Ecar$	0.010
	(0.011)
$Peak \times Ecar$	0.063***
	(0.008)
$Treat \times Shld \times Day$	-0.040***
	(0.004)
$Shld$	0.064***
	(0.001)
$Treat \times Shld \times Day \times Ecar$	0.035
	(0.022)
$Shld \times Ecar$	0.017***
	(0.005)
temp	Yes
ymean	0.583
R^2	0.725
N	39,574,316

Note: Peak: 4PM-10PM. Robust clustered standard errors at the household level in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 6 Average monthly difference (in NOK and %) between the actual and counterfactual bills of treated consumers.

Percentiles	Avg. monthly bill diff.	
	in NOK	%
p01	-315	-20.8
p05	-187	-13.9
p10	-136	-10.0
p15	-105	-7.9
p20	-87	-6.6
p25	-75	-5.7
p50	-37	-3.3
p75	-10	-1.2
p80	-5	-0.5
p85	1	0.1
p90	10	1.0
p95	27	2.8
p99	75	7.5
Mean	-52	-3.9

Table 7 Distribution of household characteristics in the treatment group across bill difference quartiles, q1-q4, and the corresponding monthly difference in NOK. Bill differences are calculated as the difference between the actual (treatment) and counterfactual (control) pricing times the observed consumption of the treated households. (1)-(4): Pre-treatment electricity consumption quartiles, Q1-Q4; (5): Electric vehicle; (6): real-time in-home-display (IHD); (7)-(10): Block-level income quartiles, Q1-Q4; (11)-(12): $</>150\text{m}^2$: Housing unit size smaller/greater than 150m^2. (13): Fireplace in the home. Columns (1)-(13) sum to 100%. (Data source for $</>150\text{m}^2$ and Fireplace is the pre-survey distributed to all households having received an IHD.)

Bill difference		Consumption qrtle				Ecar	IHD	Income qrtle				150m^2		Fire-place
Qrtile	NOK	Q1	Q2	Q3	Q4			Q1	Q2	Q3	Q4	$<$	$>$	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
q1	-144	5	16	32	48	43	36	18	22	27	31	26	39	35
q2	-54	13	32	32	22	14	29	20	28	27	25	27	31	31
q3	-23	39	32	18	11	14	17	28	28	24	21	26	13	18
q4	14	43	19	18	19	30	18	35	22	22	23	21	17	17

List of figures

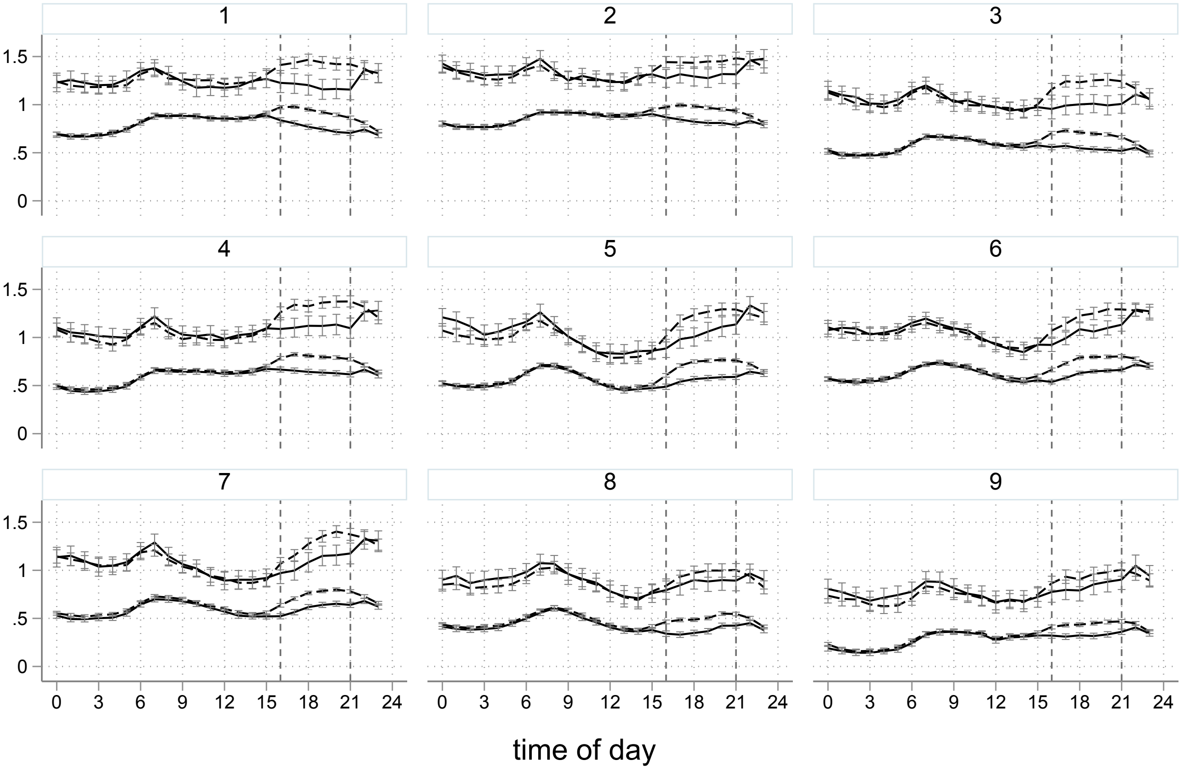


Figure 1 Log of hourly electricity consumption in the nine CPP days, differentiating the response to treatment across households with (top lines) and without electric vehicles (bottom lines). Vertical bars denote 95% confidence intervals. Each panel depicts a day with a CPP event. The nine events occurred on: 1) 10-12-2019, 2) 19-12-2019, 3) 23-01-2020, 4) 30-01-2020, 5) 13-02-2020, 6) 26-02-2020, 7) 05-03-2020, 8) 31-03-2020, 9) 28-04-2020. The solid lines depict the treatment group; dashed lines the control group. The CPP hours (4PM-10PM) are marked with vertical dashed lines.

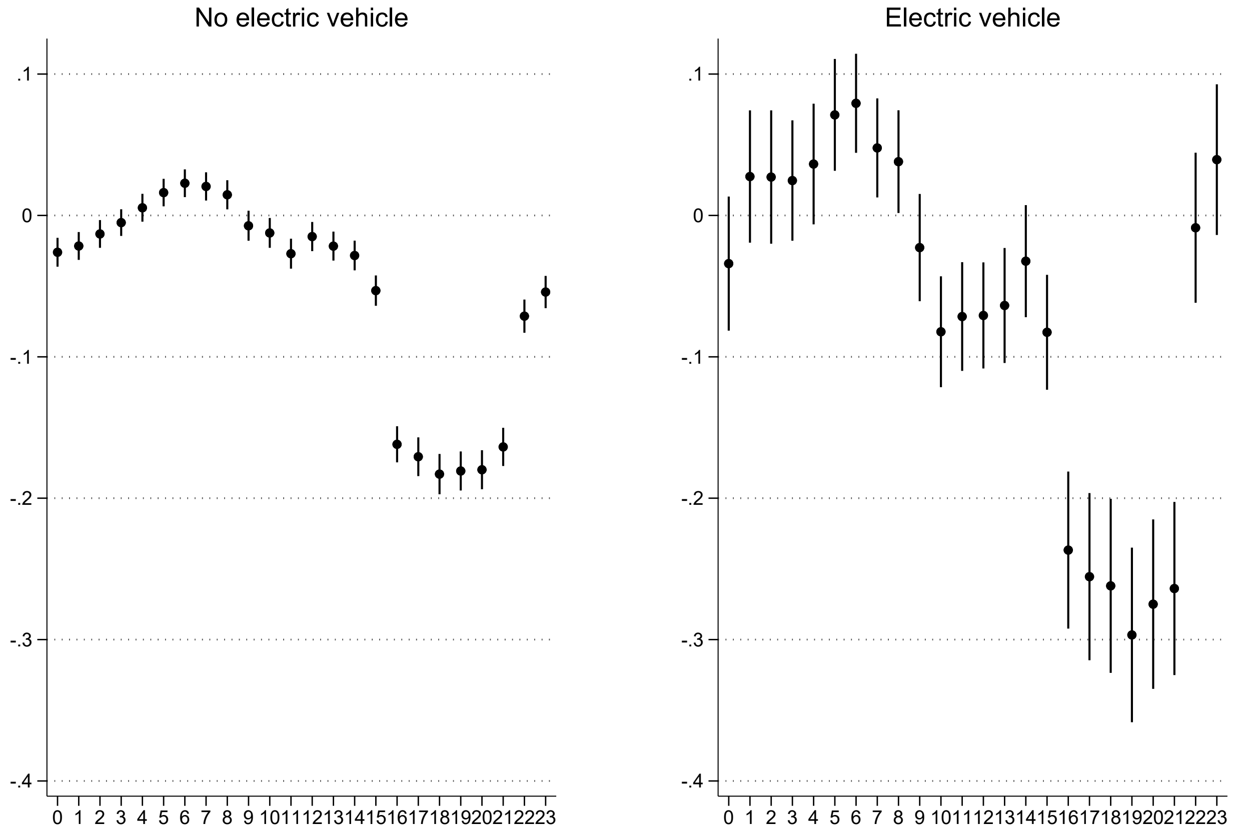


Figure 2 Effect of CPP events on log of hourly electricity consumption for each hour of a CPP day for households without an electric vehicle (left panel, N=10,733) and with an electric vehicle (right panel, N=700). Hourly effects, depicted with 90% confidence intervals, are estimated separately for households with and without an electric vehicle by modifying equation (1) to include $Treat \times Hour \times Day$, where $Hour$ denotes each hour from 12AM to 11PM. Household, date, and time of day (peak and non-peak) fixed effects are included.

Online Appendix

A Additional data description

Table A1 Descriptive statistics for the survey distributed to all households who received an IHD. The survey was conducted between 2017 and summer 2019.

	Treatment		Control	
	Mean	SD	Mean	SD
# members in HH	2.72	(1.19)	2.77	(1.24)
1	0.13	(0.34)	0.14	(0.35)
2	0.38	(0.49)	0.36	(0.48)
3	0.19	(0.40)	0.19	(0.39)
4	0.20	(0.40)	0.19	(0.40)
5+	0.09	(0.29)	0.11	(0.32)
Housing type				
Detached house	0.78	(0.41)	0.80	(0.40)
Semi-detached/townhouse	0.16	(0.37)	0.13	(0.34)
Other	0.05	(0.22)	0.07	(0.26)
Surface area (m2)	180.97	(58.31)	181.88	(59.55)
<50	0.01	(0.09)	0.00	(0.06)
51-100	0.16	(0.37)	0.18	(0.38)
101-150	0.33	(0.47)	0.30	(0.46)
151-200	0.26	(0.44)	0.29	(0.45)
201-250	0.16	(0.37)	0.14	(0.35)
>251	0.07	(0.26)	0.09	(0.28)
Building year	1975.85	(31.83)	1972.28	(27.65)
Has been renovated (0/1)	0.59	(0.49)	0.59	(0.49)
Fireplace (0/1)	0.82	(0.38)	0.81	(0.39)
# cars	1.75	(0.67)	1.75	(0.68)
0	0.01	(0.12)	0.01	(0.09)
1	0.33	(0.47)	0.36	(0.48)
2	0.54	(0.50)	0.50	(0.50)
3+	0.11	(0.32)	0.13	(0.33)
Electric or plug-in car (0/1)	0.15	(0.36)	0.12	(0.33)
Education				
High-school	0.46	(0.50)	0.39	(0.49)
Bachelor degree	0.29	(0.46)	0.34	(0.47)
Graduate degree	0.25	(0.43)	0.27	(0.44)
N	324		627	

Table A2 Responses (%) from the post-experimental survey distributed spring and summer 2021.

Did you read the program brochure?	
No	19.0
Only the side with the conservation tips	17.1
Only the side with the price information	7.0
Both	57.0
Do you remember the CPP grid charge you paid? (Scale from 1 to 10 NOK)	
<5 NOK	36.0
5-9 NOK	41.6
10 NOK	22.7
What is(are) your heating source(s)?	
Panel heaters	60.4
Heat pump	56.3
Wood	75.0
Central heating	5.2
Oil	1.6
How did you change your behavior in response to CPP events?	
Lower indoor temperature	41.3
Reprogram thermostat	21.1
Use more wood	47.1
Shorter showers	47.0
Change dinner plans	29.3
Change use of appliances	80.0
Change EV charging time	20.2
What motivated you to change your behavior in response to CPP events?	
To save on my energy bill	72.0
To reduce the need for future grid investment	3.8
For moral reasons	4.6
For environmental reasons	2.7
How did the COVID restrictions affect your response on March 31 and April 28?	
Made it harder	14.0
Made it easier	10.0
Made no difference	77.5
Do you think you saved on your energy bill with the CPP program?	
Yes	23.5
No, higher bill	16.2
About the same	23.3
Not sure	37.1
N from treatment group	560

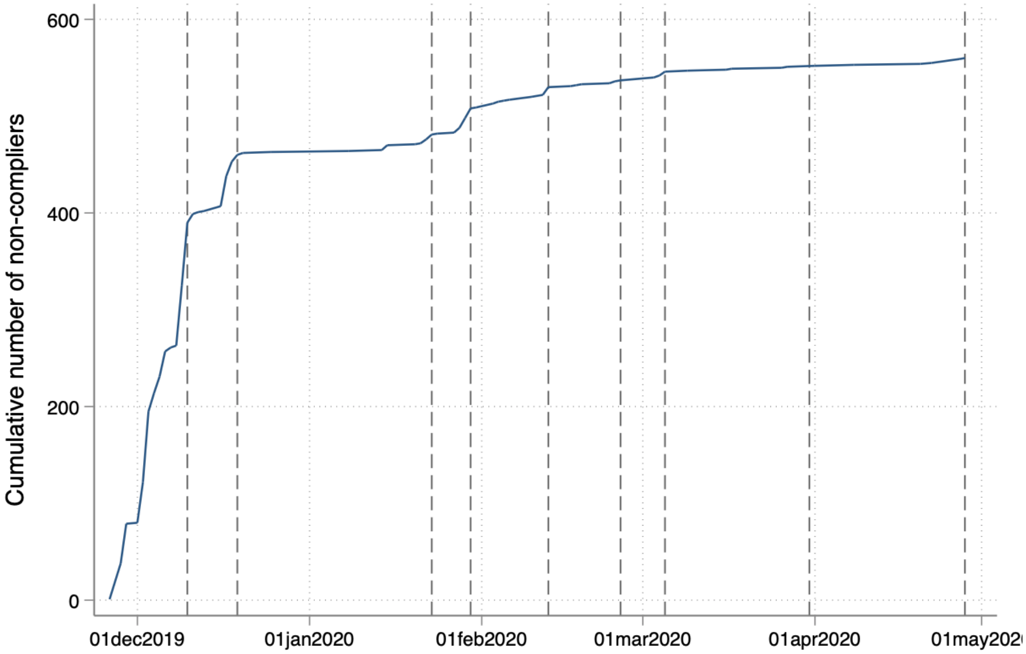


Figure A1 Cumulative distribution of the number of non-compliers. The nine CPP events are depicted as dashed lines. By the end of the intervention, a total of 560 customers had requested to be taken out of the treatment group. Of those, 390 (70%) did so prior to the first CPP event.

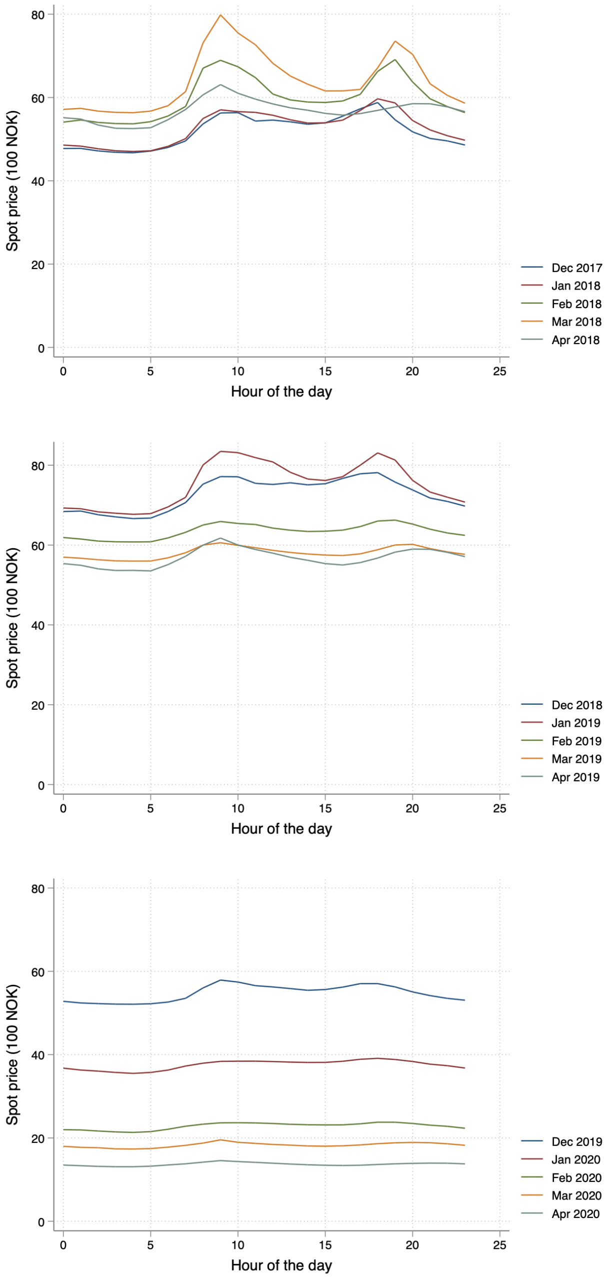


Figure A2 Average hourly spot price by month (December to April) for the winters 2017-2018 (top left), 2018-2019 (top right), and 2019-2020 (bottom).

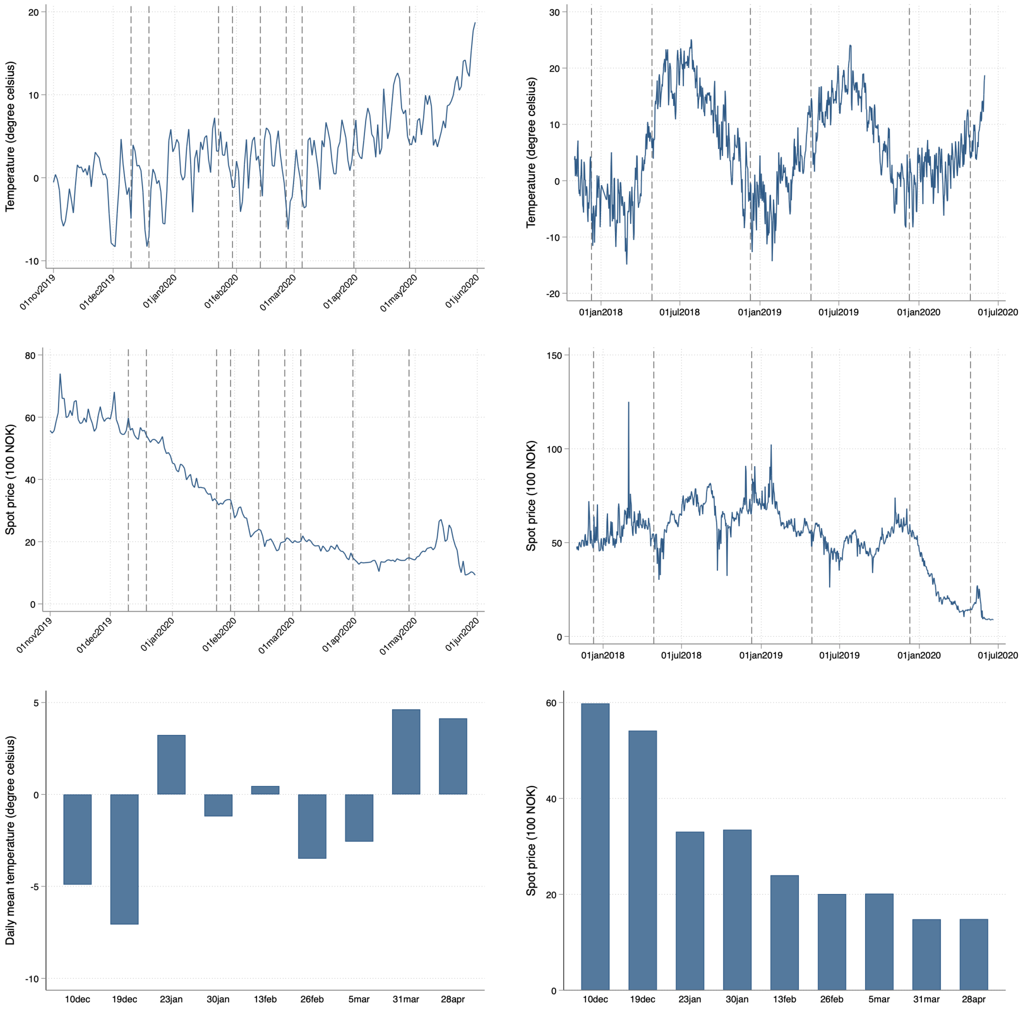
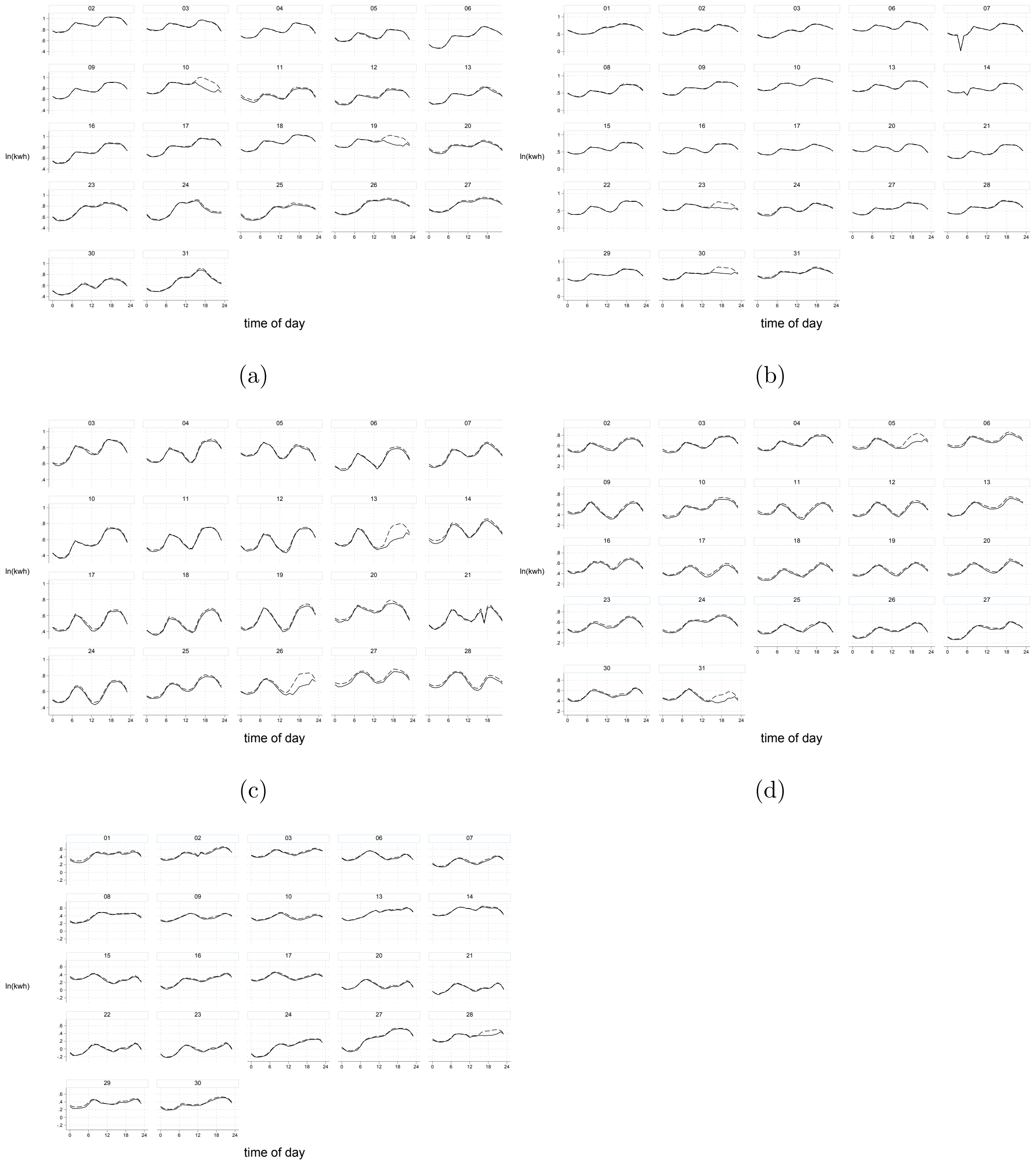


Figure A3 Average daily temperature and spot price. Top panels show temperature and middle panels show the spot price, while left panels show the November 2019 to May 2020 period with the nine CPP events depicted as dashed lines, and right panels show the November 2017 to May 2020 period with 10 December and 28 April depicted as dashed lines in each year. Bottom panels show temperature (left) and spot price (right) for each of the nine CPP events.



(a)

(b)

(c)

(d)

(e)

Figure A4 Log of hourly electricity consumption. Every frame depicts a day. All days during the five months of the experiment, from December 2019 (panel (a)) to April 2020 (panel (e)) are shown, with weekends excepted. Solid line depicts the treatment group; dashed line the control group.

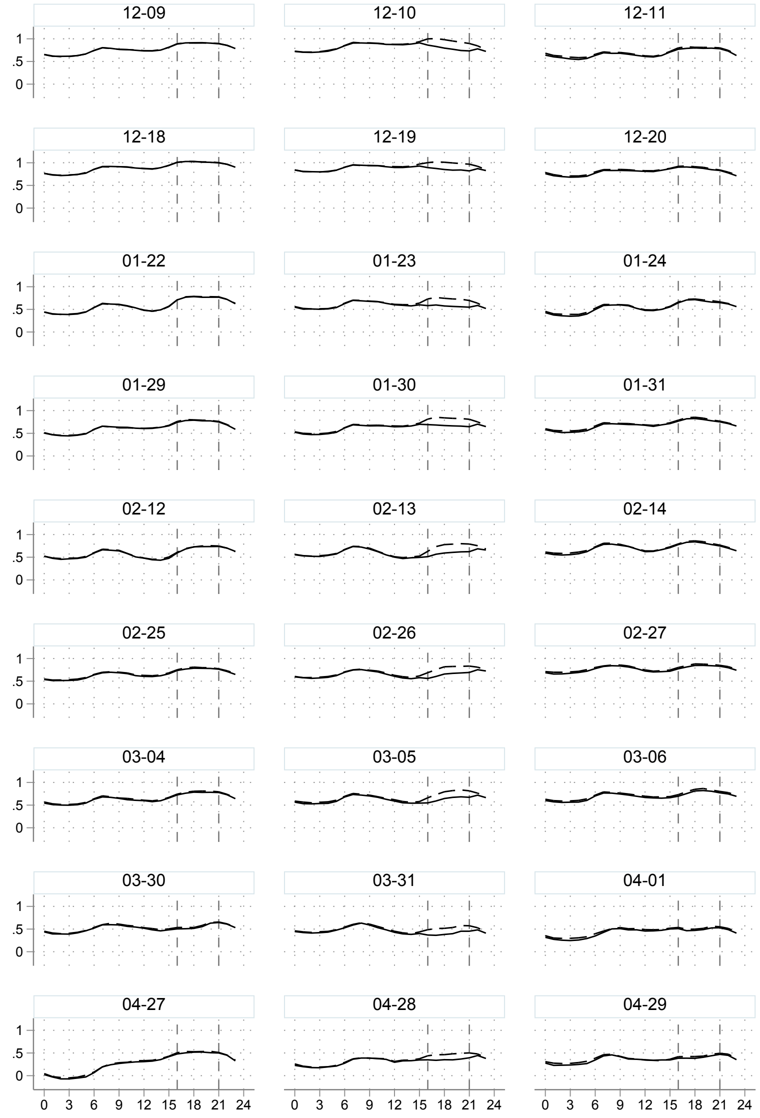


Figure A5 Log of hourly electricity consumption on the nine CPP days (middle panels), including one day prior (left panels) and one day post CPP event (right panels). Each CPP event is depicted on a different row, with the 1st CPP event on December 10th on the top row and the 9th CPP event on April 28th on the bottom row. The nine events occurred on: 1) 10-12-2019, 2) 19-12-2019, 3) 23-01-2020, 4) 30-01-2020, 5) 13-02-2020, 6) 26-02-2020, 7) 05-03-2020, 8) 31-03-2020, 9) 28-04-2020. Solid line depicts the treatment group; dashed line the control group. The CPP hours (4PM-10PM) are marked with vertical dashed lines.

B Additional results

For each specification in Table B1, CPP events are associated with a 0.15-log point reduction in peak electricity consumption in the treatment group relative to the control group. This is slightly higher than in the model with household fixed effects (Table 2). Again, across all specification, there is no sign of load shifting to non-CPP hours, but rather a small persistent reduction effect on the two days following a CPP event.

Electric vehicle treatment heterogeneity is shown in columns (3) and (5). Although electric vehicle households consume more electricity (the coefficient for $Ecar$ is 0.43 log points), their response to CPP is not significantly different from non-electric vehicle households for specifications without household fixed effects.

Load shifting to shoulder hours is shown in columns (4) and (5), without and with allowing for heterogeneity across electric vehicle households, respectively. Results in column (4) suggest that the reduction in electricity consumption outside the peak hours on a CPP day largely took place in the shoulder hours, with a reduction of 0.042 log points for the treatment group relative to the control group. The reduction in electricity consumption in the shoulder hours is not significantly different when examining the response of electric vehicle households in the treatment group ($Treat \times Shld \times Day \times Ecar$; column (5)), consistent with Table 2 with household fixed effects.

Table B1 Effect of CPP events on log of hourly electricity consumption, without household fixed effects. (1) and (2): Equation (1) either without or with temperature controls. (3): Equation (1) with electric vehicle treatment heterogeneity. (4) and (5): Equation (2) either without or with electric vehicle treatment heterogeneity. All specifications include date and time of day (peak and non-peak) fixed effects. In columns (4) and (5), time of day fixed effects consist of peak, non-peak, and shoulder.

	(1)	(2)	(3)	(4)	(5)
$Treat \times Peak \times Day$	-0.153***	-0.152***	-0.151***	-0.152***	-0.151***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$Treat \times NPeak \times Day$	-0.015	-0.016	-0.019	-0.006	-0.010
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)
$Treat \times Peak \times Post$	-0.039***	-0.031**	-0.033**	-0.031**	-0.032**
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$Treat \times NPeak \times Post$	-0.016	-0.018	-0.022	-0.018	-0.022
	(0.014)	(0.014)	(0.015)	(0.014)	(0.015)
$Peak$	0.138***	0.143***	0.140***	0.161***	0.157***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
$Ecar$			0.429***		0.425***
			(0.023)		(0.023)
$Treat \times Peak \times Day \times Ecar$			-0.024		-0.024
			(0.038)		(0.038)
$Treat \times NPeak \times Day \times Ecar$			0.054		0.053
			(0.034)		(0.035)
$Treat \times Peak \times Post \times Ecar$			0.012		0.012
			(0.033)		(0.033)
$Treat \times NPeak \times Post \times Ecar$			0.048		0.048
			(0.034)		(0.034)
$Peak \times Ecar$			0.059***		0.063***
			(0.006)		(0.007)
$Treat \times Shld \times Day$				-0.042***	-0.042***
				(0.003)	(0.003)
$Shld$				0.065***	0.064***
				(0.001)	(0.001)
$Treat \times Shld \times Day \times Ecar$					0.002
					(0.011)
$Shld \times Ecar$					0.017***
					(0.005)
temp	No	Yes	Yes	Yes	Yes
R^2	0.046	0.046	0.062	0.047	0.062
N	41,443,269	41,443,269	41,443,269	41,443,269	41,443,269

Note: Robust clustered standard errors at the household level in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table B2 Effect of CPP on log of hourly electricity consumption for households based on pre-treatment electricity consumption quartiles for non-electric vehicle households (columns (1) - (4)) and electric vehicle households (columns (5) - (8)). Note the lower number of observations for households with electric vehicles. Specifically, columns (5) - (8) consist of 54, 51, 73, 57 treated households, and 120, 124, 102, and 118 control households, in each consumption quartile respectively. All specifications use equation (2). All specifications include household, date, and time of day (peak, non-peak, and shoulder) fixed effects.

	Consumption quartile for non-EV households				Consumption quartile for EV households			
	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Treat \times Peak \times Day$	-0.106***	-0.118***	-0.164***	-0.143***	-0.198***	-0.178***	-0.265***	-0.163***
	(0.009)	(0.008)	(0.010)	(0.010)	(0.037)	(0.039)	(0.051)	(0.039)
$Treat \times NPeak \times Day$	0.006	0.006	0.005	0.006	-0.007	-0.000	-0.001	-0.004
	(0.006)	(0.004)	(0.004)	(0.003)	(0.019)	(0.016)	(0.017)	(0.013)
$Treat \times Peak \times Post$	-0.013**	-0.005	-0.022***	-0.015***	-0.074***	-0.002	-0.023	-0.045***
	(0.006)	(0.004)	(0.003)	(0.003)	(0.020)	(0.018)	(0.015)	(0.014)
$Treat \times NPeak \times Post$	-0.008*	-0.007**	-0.009***	-0.004*	0.000	0.009	-0.000	-0.003
	(0.004)	(0.003)	(0.003)	(0.002)	(0.015)	(0.011)	(0.010)	(0.008)
$Peak$	0.230***	0.132***	0.134***	0.129***	0.279***	0.232***	0.217***	0.194***
	(0.005)	(0.003)	(0.003)	(0.002)	(0.017)	(0.011)	(0.012)	(0.011)
$Treat \times Shld \times Day$	-0.035***	-0.035***	-0.044***	-0.040***	-0.046*	-0.013	-0.022	-0.018
	(0.007)	(0.005)	(0.004)	(0.004)	(0.026)	(0.028)	(0.018)	(0.019)
$Shld$	0.112***	0.050***	0.047***	0.045***	0.125***	0.091***	0.080***	0.073***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.011)	(0.009)	(0.008)	(0.008)
$temp$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$ymean$	-0.376	0.481	0.846	1.279	0.287	0.987	1.221	1.517
R^2	0.537	0.325	0.349	0.465	0.525	0.248	0.265	0.342
N	9,789,632	9,807,411	9,808,868	9,811,196	636692	637,851	637,707	637,748

Note: Robust clustered standard errors at the household level in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table B3 Effect of CPP on log of hourly electricity consumption for each one of the nine CPP events. The nine events occurred on: (1) 10-12-2019, (2) 19-12-2019, (3) 23-01-2020, (4) 30-01-2020, (5) 13-02-2020, (6) 26-02-2020, (7) 05-03-2020, (8) 31-03-2020, (9) 28-04-2020. For each CPP event, electricity consumption covers the period starting three days after the previous CPP event (or December 1 2019 for the first CPP event) and up to two days after a CPP event. All specifications use equation (2) with electric vehicle treatment heterogeneity. All specifications include household, date, and time of day (peak, non-peak, and shoulder) fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Treat \times Peak \times Day$	-0.163***	-0.125***	-0.139***	-0.165***	-0.159***	-0.157***	-0.131***	-0.155***	-0.040***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$Treat \times NPeak \times Day$	-0.012***	-0.001	-0.000	0.007**	0.010***	0.027***	0.009**	0.031***	-0.038***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)
$Treat \times Peak \times Post$	-0.019***	-0.013**	-0.017***	-0.008*	-0.006	-0.023***	-0.017***	-0.005	0.018***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
$Treat \times NPeak \times Post$	-0.024***	-0.006	-0.008**	-0.010***	-0.006*	-0.001	-0.006*	-0.007*	-0.019***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.005)
$Peak$	0.165***	0.166***	0.179***	0.179***	0.172***	0.155***	0.151***	0.128***	0.088***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Treat \times Peak \times Day \times Ecar$	-0.092***	-0.058**	-0.051	-0.079**	-0.065**	-0.072**	-0.026	-0.033	-0.035
	(0.032)	(0.029)	(0.032)	(0.033)	(0.031)	(0.031)	(0.033)	(0.031)	(0.032)
$Treat \times NPeak \times Day \times Ecar$	0.005	0.003	0.054***	0.015	0.029**	-0.014	0.041***	-0.003	0.044**
	(0.015)	(0.016)	(0.016)	(0.014)	(0.013)	(0.017)	(0.015)	(0.015)	(0.018)
$Treat \times Peak \times Post \times Ecar$	0.006	-0.044*	0.025	-0.045**	-0.049**	-0.071***	0.019	0.019	-0.008
	(0.017)	(0.022)	(0.019)	(0.018)	(0.021)	(0.021)	(0.019)	(0.017)	(0.020)
$Treat \times NPeak \times Post \times Ecar$	0.011	0.000	0.032**	0.004	0.018	-0.012	0.052***	-0.010	0.022
	(0.012)	(0.015)	(0.013)	(0.011)	(0.012)	(0.016)	(0.012)	(0.011)	(0.014)
$Peak \times Ecar$	0.067***	0.057***	0.059***	0.070***	0.073***	0.038***	0.061***	0.064***	0.072***
	(0.008)	(0.008)	(0.007)	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)	(0.010)
$Treat \times Shld \times Day$	-0.032***	-0.017***	-0.047***	-0.050***	-0.058***	-0.085***	-0.052***	-0.069***	0.075***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$Shld$	0.072***	0.084***	0.084***	0.064***	0.065***	0.050***	0.056***	0.033***	0.039***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
$Treat \times Shld \times Day \times Ecar$	0.025	0.039*	-0.034	0.007	0.012	0.006	0.024	-0.019	-0.028
	(0.023)	(0.022)	(0.025)	(0.020)	(0.021)	(0.023)	(0.020)	(0.024)	(0.027)
$Shld \times Ecar$	0.027***	0.019***	0.022***	0.024***	0.021***	0.004	0.014**	0.003	0.020***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
$temp$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$ymean$	0.773	0.765	0.662	0.634	0.663	0.614	0.684	0.530	0.310
R^2	0.808	0.805	0.771	0.795	0.787	0.772	0.797	0.748	0.691
N	3,301,324	2,476,042	9,715,194	1,925,169	3,849,362	3,941,441	2,290,540	7,134,668	7,690,184

Note: Robust clustered standard errors at the household level in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

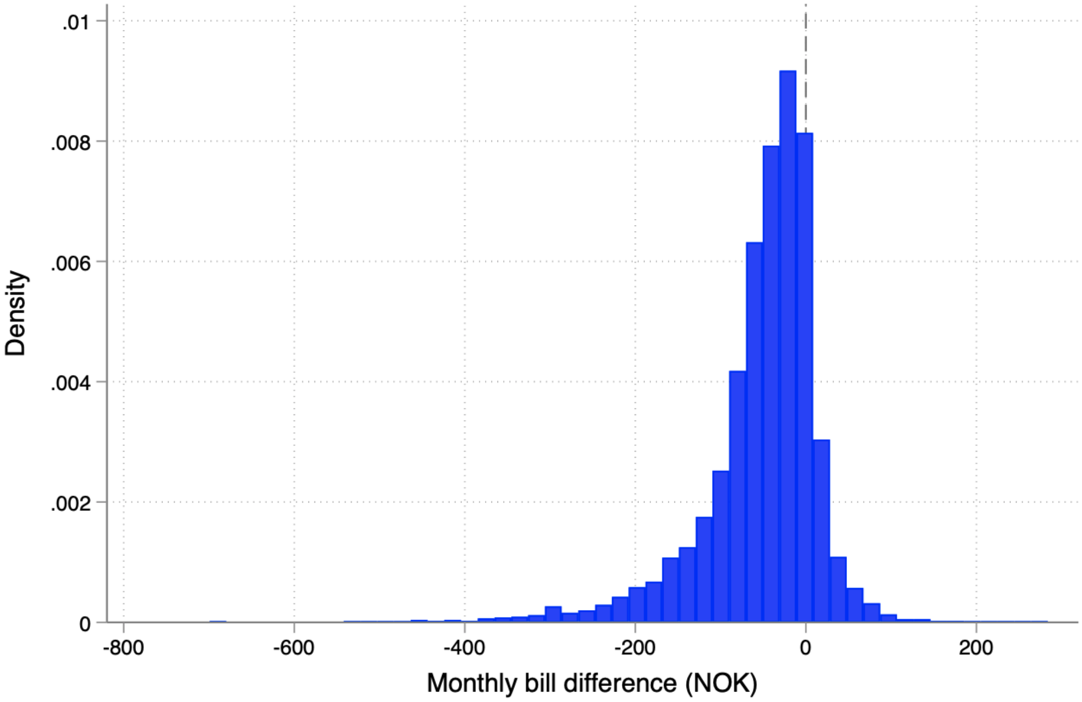


Figure B1 Distribution of the average monthly bill difference (in NOK) between the actual bill (with CPP) and the counterfactual bill (with control pricing) for consumers in the treatment group. The dashed line indicates no difference.

C Communication with customers in treatment group

C.1 Timeline overview

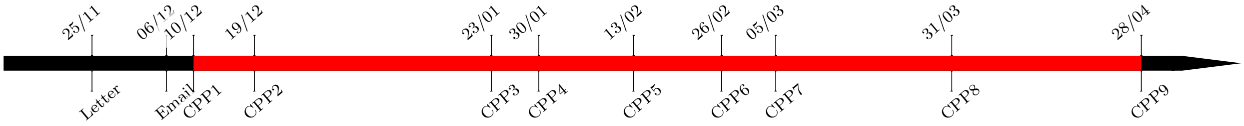


Figure C1 Timeline overview of the CPP intervention and communication with the customers in 2019-2020. The CPP intervention, depicted in red, consists of nine CPP events that took place between December 10 2019 and April 28 2020. Sample selection and randomization was completed on October 23 2019, prior to the experiment.

C.2 First contact: Information sent in the mail in November

C.2.1 Letter about participation in the CPP program, with opt-out

Ringerikskraft
Nett

Plass til adresse

Pilotprosjekt for ny nettleiemodell

Hei,

Din husstand er tilfeldig plukket ut til å delta i vårt pilotprosjekt for ny nettleiemodell. Sammen med 4000 av nettkundene våre får du fra 1. desember mulighet til å være med å teste og gi tilbakemeldinger på det som kan bli fremtidens nettleiemodell.

Hvorfor?

Måten vi bruker strøm på, og hvor mye strøm vi har behov for, er i endring. Elektrifisering av samfunnet, det vil si at stadig mer går på strøm, er et viktig og positivt klimatiltak. Ved økt strømbruk belaster vi kapasiteten i nettet stadig mer. Fortsetter vi å øke forbruket vil det være behov for å øke kapasiteten, en investering som er kostbar og som øker nettleien. Målet vårt er at denne nye modellen skal hjelpe oss alle med å få et mer bevisst forhold til hvordan vi bruker strøm, slik at vi unngår kapasitetsutfordringer og unødige kostnadsøkninger.

Hva betyr dette for meg?

Som pilotkunde får du bedre mulighet til å spare nettleie enn med tidligere prismodell. Det vil i praksis si at du, gjennom et bevisst forhold til eget strømforbruk, kan påvirke hvor mye du bruker og hvor mye strømregningen kommer på. Du får også mulighet til å gi tilbakemeldinger og innspill underveis slik at vi sammen kan skape en god modell som kan bidra til at vi unngår store investeringer i fremtiden. Om vi klarer å utnytte den gode kapasiteten vi allerede har gjennom hele døgnet, vil vi sammen klare å holde igjen investeringer som også påvirker nivået på nettleien.

Hva skjer videre?

10 dager i året blir du varslet på SMS i forkant av en dag med peaktimer mellom klokken 16.00 og 22.00. Dette gjelder hovedsakelig i vintermånedene hvor vi bruker mest strøm og kapasiteten er minst. Dersom du er bevisst strømforbruket ditt i peaktimene og gjør noen sparetiltak vil du spare penger. Om du ikke gjør noen tiltak og bruker strøm som vanlig vil nettleien koste omtrent like mye som før. Bruker du mer strøm enn du pleier i peaktimene må du belage deg på at det vil koste deg ekstra.

Med varsling i forkant av dager med peaktimer håper vi at vi kan oppfordre og inspirere til å bruke mindre strøm når kapasiteten er begrenset og prisene er høyere. Vi håper du vil bli med oss videre i prosjektet og hjelpe oss med å bygge fremtidens prismodell! Gjennom deltagelse i prosjektet gjør du oss i bedre stand til å levere bedre tjenester fremover, samtidig som du påvirker din egen strømregning.

Kontaktinformasjon på baksiden →

Ringerikskraft Nett AS | Besøksadresse: Hvervenmoveien 33, 3511 Hønefoss | Postadresse: Postboks 522, 3504 Hønefoss |
kundeservice@ringerikskraftnett.no | 32 11 96 50 | Org.nr: 987 626 844 | **ringerikskraftnett.no**

Ringerikskraft
Nett

Kontakt oss

Har du har spørsmål eller kommentarer til prosjektet eller nettleiemodellen – ikke nøl med å ta kontakt! Du kan ta kontakt med oss når som helst i pilotperioden, så hjelper vi deg med det du måtte lure på.

Om du ikke ønsker å delta ber vi deg kontakte oss på 32 11 96 72, så vil kundesenteret vårt hjelpe deg.

Du kan også lese mer om prosjektet på www.ringerikskraftnett.no/pilot

Åpningstider
Ring kundesenteret på 32 11 96 72
Vi holder åpnet mandag til fredag kl. 08:00 til 16:00
Fra 25.11 til 6.12 har vi utvidet åpningstid på telefon 32 11 96 72 til klokken 18:00

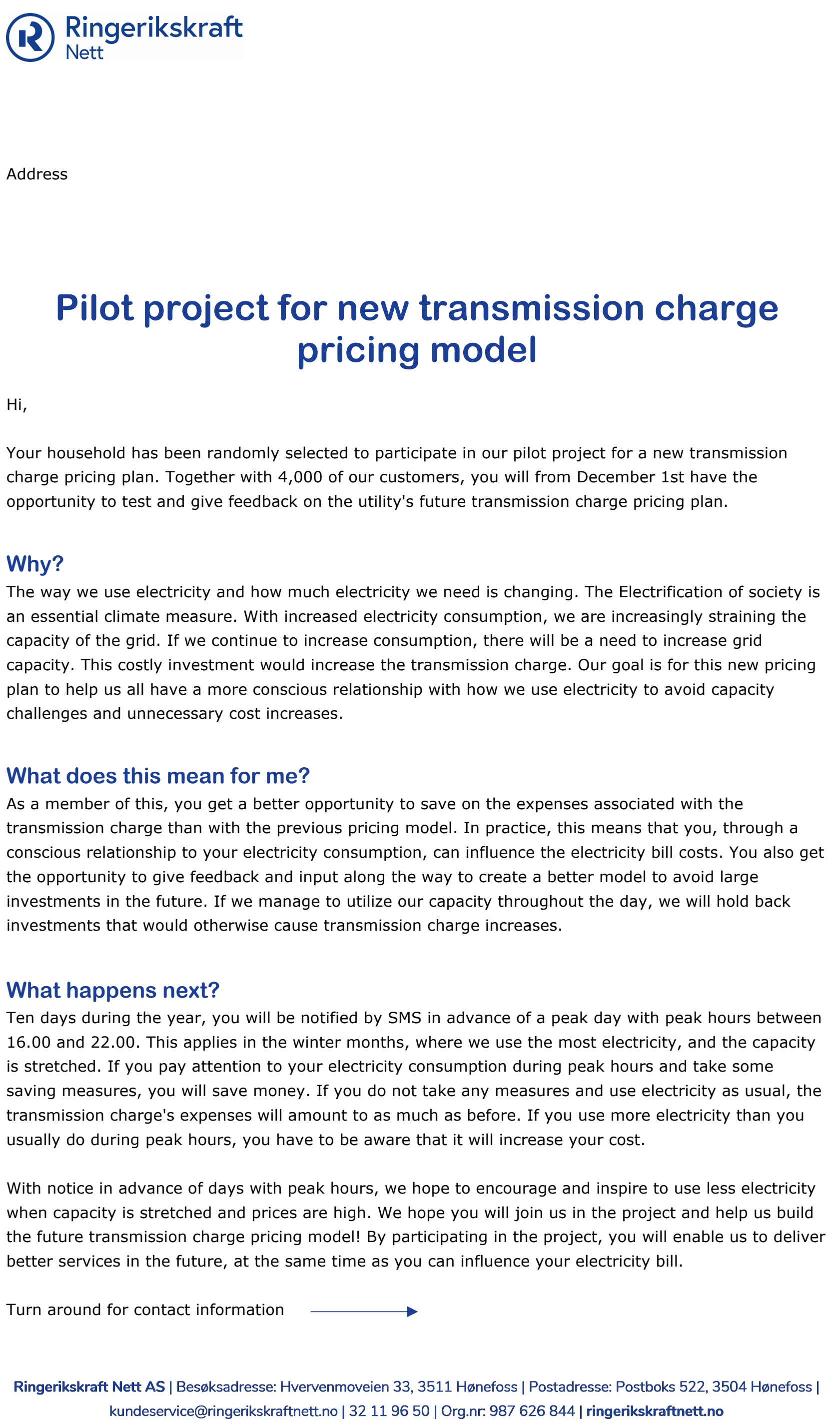
Med vennlig hilsen

Live Dokka
Prosjektleder for pilotprosjektet

Jan-Erik Brattbakk
Nettsjef Ringerikskraft Nett

Ringerikskraft Nett AS | Besøksadresse: Hvervenmoveien 33, 3511 Hønefoss | Postadresse: Postboks 522, 3504 Hønefoss |
kundeservice@ringerikskraftnett.no | 32 11 96 50 | Org.nr: 987 626 844 | **ringerikskraftnett.no**

English translation



Ringerikskraft
Nett

Address

Pilot project for new transmission charge pricing model

Hi,

Your household has been randomly selected to participate in our pilot project for a new transmission charge pricing plan. Together with 4,000 of our customers, you will from December 1st have the opportunity to test and give feedback on the utility's future transmission charge pricing plan.

Why?

The way we use electricity and how much electricity we need is changing. The Electrification of society is an essential climate measure. With increased electricity consumption, we are increasingly straining the capacity of the grid. If we continue to increase consumption, there will be a need to increase grid capacity. This costly investment would increase the transmission charge. Our goal is for this new pricing plan to help us all have a more conscious relationship with how we use electricity to avoid capacity challenges and unnecessary cost increases.

What does this mean for me?

As a member of this, you get a better opportunity to save on the expenses associated with the transmission charge than with the previous pricing model. In practice, this means that you, through a conscious relationship to your electricity consumption, can influence the electricity bill costs. You also get the opportunity to give feedback and input along the way to create a better model to avoid large investments in the future. If we manage to utilize our capacity throughout the day, we will hold back investments that would otherwise cause transmission charge increases.

What happens next?

Ten days during the year, you will be notified by SMS in advance of a peak day with peak hours between 16.00 and 22.00. This applies in the winter months, where we use the most electricity, and the capacity is stretched. If you pay attention to your electricity consumption during peak hours and take some saving measures, you will save money. If you do not take any measures and use electricity as usual, the transmission charge's expenses will amount to as much as before. If you use more electricity than you usually do during peak hours, you have to be aware that it will increase your cost.

With notice in advance of days with peak hours, we hope to encourage and inspire to use less electricity when capacity is stretched and prices are high. We hope you will join us in the project and help us build the future transmission charge pricing model! By participating in the project, you will enable us to deliver better services in the future, at the same time as you can influence your electricity bill.

Turn around for contact information →

Ringerikskraft Nett AS | Besøksadresse: Hvervenmoveien 33, 3511 Hønefoss | Postadresse: Postboks 522, 3504 Hønefoss |
kundeservice@ringerikskraftnett.no | 32 11 96 50 | Org.nr: 987 626 844 | **ringerikskraftnett.no**

Contact us

If you have any questions or comments about the project or the grid rental model - do not hesitate to get in touch! You can contact us at any time during the pilot period, and we will help you with any questions you may have.

If you do not want to participate, please contact us at 32 11 96 72, and our customer center will help you.

You can also read more about the project at www.ringerikskraftnett.no/pilot

Opening hours

Call the customer center on32 11 96 72

We are open Monday to Friday from 08:00 to 16:00

From 25.11 to 6.12, we have extended the opening hours on the phone 32 11 96 72 until 18:00

Best regards,

Live Dokka
Project manager for the pilot project

Jan-Erik Brattbakk
Head of Grid at Ringerikskraft Nett

C.2.2 Two-sided brochure

Ringerikskraft
Nett

NY PRISMODELL

Bruk mindre når det koster mer

Med bevisst strømbruk kan vi unngå begrenset kapasitet og kostnadsøkninger.

UTVIKLINGEN

Elektrifiseringen av samfunnet

Hvordan kom vi hit?
Elektrifiseringen fører til økt belastning: Klokken 16.00 kommer alle hjem fra jobb og skole. Elbilene lades, huset varmes opp, du tar en dusj, tørketrommel og oppvaskmaskinen går og middagen står i ovnen. Når alle bruker mye strøm samtidig, kan det enkelte dager oppstå kapasitetsutfordringer.

Økt forbruk belaster kapasiteten i nettet – og kapasiteten er ikke uendelig.
Dette gjelder i hovedsak på kalde dager og i ettermiddagstimene. Fortsetter vi å øke forbruket på disse dagene, og om alle f.eks. lader elbilen på ettermiddagen, så vil det være behov for å gjøre store investeringer. Investeringer i økt kapasitet er kostbart og vil øke nettleien.

Bedre sammen

Hva kan vi gjøre sammen for å unngå dyre investeringer? Sammen med kundene våre vil vi undersøke hvordan vi kan bygge opp best mulig ordning for nettleie for både kundene, samfunnet og nettselskapet. Om vi i fellesskap blir mer bevisst strømbruken vår og fordeler den mer utover døgnet, kan vi unngå kapasitetsutfordringer.

Peaktimer og prising

Jo mer strøm du bruker, jo høyere blir strømregningen. Slik er det i dag, og slik vil det naturlig nok alltid være. Med den nye modellen er det lettere å spare penger enn tidligere.

Tar du hensyn til peaktimene som kommer 10 dager i året og justerer strømbruken, så påvirker du direkte sluttsummen på regningen. Forskjellen mellom en vanlig ettermiddag og en ettermiddag med peaktimer kan se slik ut:

En vanlig tirsdag i november uten peaktimer (off peak) koster strømmen 1 kr/kWh*. Ettermiddagen etter er det peaktimer mellom 16.00 og 22.00. Da koster strømmen 10 kr/kWh.*

Kan du utsette å bruke tørketrommelen og lade elbilen midt i peaktimene 10 dager i året? Da vil du spare penger og samtidig sørge for mindre belastning på strømnettet når kapasiteten er minst.

Peaktimene vil alltid være varslet, og du kan selv velge om du ønsker å gjøre tiltak eller ikke. Siden nettleieprisen går ned på alle andre dager enn peakdagene, så vil du fortsatt ende opp med tilnærmet lik total nettleie som tidligere modell dersom du ikke ønsker å flytte forbruket.

Om du bruker tørketrommel 1 time og lader elbilen på 7 kW i tre timer bruker du omtrent 23 kWh.

Off peak vil det koste **23 kr*** I **peaktimene** vil det koste **230 kr***

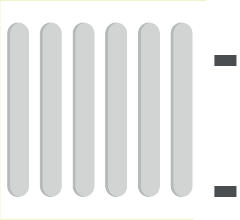
**Prisen på 1 kr/kWh og 10 kr/kWh er en gjennomsnittspris på både strøm og nettleie. Årsaken er at strømprisen varierer fra time til time. Nettleien varier kun mellom vanlig pris (off peak) og peaktimer.*

Ring 32 11 96 72 for henvendelser om pilotprosjektet. Les mer på **ringerikskraftnett.no/pilot**

Ringerikskraft
Nett

Nyttige sparetips

De aller fleste kan tenke seg å spare penger på å bruke mindre strøm, men er usikker på hvordan de gjør det samtidig som de skal få hverdagen til å gå rundt. Her er noen tips til sparing som skal opprettholde komforten.



Reduser mengden strøm til oppvarming fra panelovner og varmekabler

✓ Kan du skru ned temperaturen en grad eller to i rom du ikke bruker så ofte? Eller programmere ovnene til bestemte tidspunkter av døgnet?

✓ Med varmepumpe kan du få mer varme med mindre strøm.

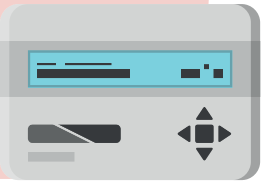
✓ På kalde dager kan det være lurt å fyre med ved om man har mulighet til det.

Kan du styre varmen?

✓ Kan du varme opp huset litt før du kommer hjem fra jobb? Da kan du senke temperaturen litt på ettermiddagen når strømmen gjerne er litt dyrere enn på dagtid. Og kanskje også holde varmen med vedfyring.

✓ En del varmepumper kan styres. Sjekk om du kan programmere din til bestemte tider av døgnet.

✓ Skal du ha ny varmtvannsbereder? Det kommer stadig nye løsninger på markedet som er smartere og mer effektive enn tidligere modeller.

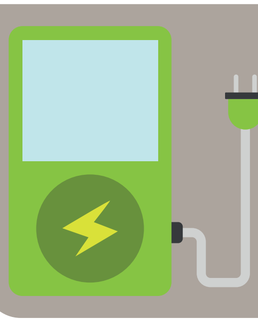


Alle trenger varmtvann, men klarer du å spare litt?

✓ Å fylle et helt badekar bruker mye mer varmtvann enn en dusj. Kutter du ned antall dager med badekar, så kan du spare mye på strømregningen.

✓ Kan noen av dusjene i løpet av uken gjøres unna på noen få minutter fremfor en halvtime? Da er det mye å spare!

✓ Har du tatt oppvasken fremfor å sette i gang oppvaskmaskinen for å spare strøm? Det er ikke sikkert det var lønnsomt. Oppvaskmaskiner er energieffektive, og man bruker gjerne mye varmtvann ved oppvask for hånd. Husk heller å fylle opp maskinen før du starter den.



Lad elbilen på natten

✓ Elbilen trekker mye strøm når den lader. Lad gjerne på natten når resten av strømforbruket er lavt.

English translation

Ringerikskraft
Nett

NEW PRICING MODEL

Use less when electricty is expensive

With conscious electricity consumption, we can avoid limited capacity and cost increases.

GOING FORWARD

The electrification of society

How did we get here?
The electrification leads to an increased load: At 16.00, everyone comes home from work and school. Electric cars are being charged, the house is heated, you take a shower, the dryer and the dishwasher runs, and dinner is cooked. When everyone uses a lot of electricity at the same time, capacity challenges can arise on some days.

Increased consumption strains the capacity of the grid - the capacity is not infinite.
Capacity constraints mainly apply to cold days and in the afternoon hours. If we continue to increase consumption on such days and charge our electric cars in the afternoon, there will be a need to make large investments in the grid. Such investments are expensive and will increase the transmission charge.

Better together

What can we do together to avoid expensive investments?
Together with our customers, we will investigate how we can find the best transmission charge scheme for both customers, the community, and grid companies. If we become more aware of our electricity consumption and distribute it evenly throughout the day, we can avoid capacity challenges.

Peakhours and pricing

The more electricity you use, the higher the electricity bill. This is how it is today, and this is how it will be.
With the new model, it is easier to save money than before.

If you consider the peak hours that come ten days in the year and adjust the power consumption, you can reduce your electricity bill. The difference between an ordinary afternoon and an afternoon with peak hours can look like this:

On an ordinary Tuesday in November without peak hours (off-peak), the electricity costs NOK 1 / kWh *. In the afternoon the day after, there are peak hours between 16.00 and 22.00. Then the electricity costs 10 kr / kWh. *

If you avoid using the dryer and charging the electric car during the peak hours ten days a year, you will save money and at the same time ensure less load on the power grid when capacity is limited.

The peak hours will always be notified the day before, and you can choose whether you want to take action or not. Since the transmission charge is reduced the rest of the time, you will probably end up with approximately the same transmission charge as the ordinary model if you do not move your consumption.

If you use a dryer for 1 hour and charge the electric car at 7 kW for three hours, you use approximately 23 kWh.

Off-peak this will cost **23 NOK*** During **peak hours this will cost 230 NOK***

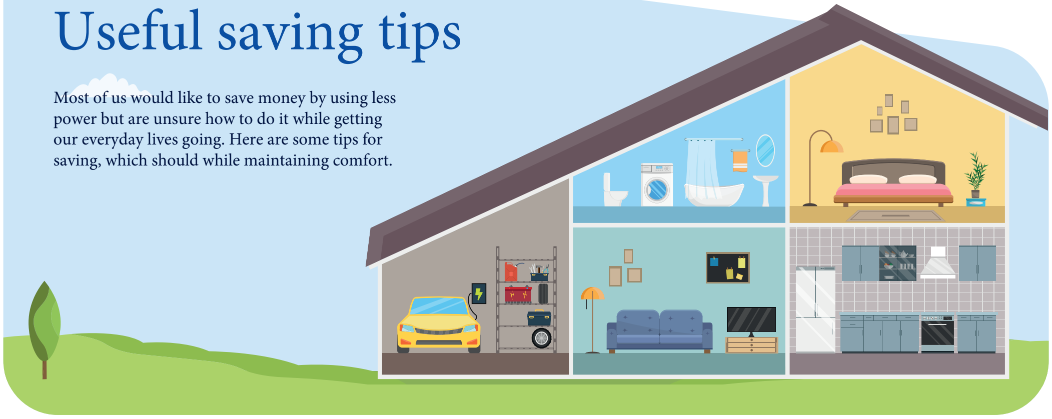
**NOK 1 / kWh and NOK 10 / kWh's price is an average price for both electricity and transmission charge. The reason is that the price of electricity varies from hour to hour. The transmission charge only varies between the regular price (off peak) and peak hours.*

Call 32 11 96 72 for inquiries about the pilot project. Read more at **ringerikskraftnett.no/pilot**

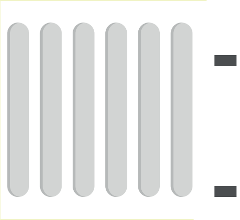
Ringerikskraft
Nett

Useful saving tips

Most of us would like to save money by using less power but are unsure how to do it while getting our everyday lives going. Here are some tips for saving, which should while maintaining comfort.



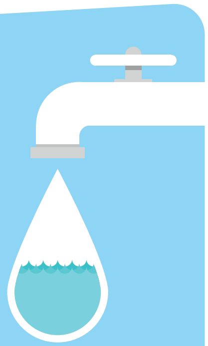
Reduce electricity for heating from panel heaters and floor heating



Can you turn down the temperature one or two degrees in rooms you do not use often? Or program the panel heaters for certain hours of the day? With a heat pump you can get more heat with less power.

On cold days, you may want to use a wood stove if you have one.

Everybody needs hot water, but can you manage to save a little?



Filling an entire bathtub uses much more hot water than taking a shower. If you reduce the days you take a bath, you may save a lot on your electricity bill.

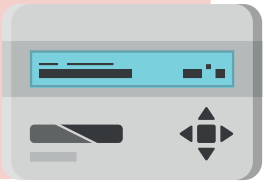
Can you take a shower that lasts a few minutes rather than half an hour? Then there is a lot to save!

Have you done the dishes instead of starting the dishwasher to save electricity? It's not sure it was profitable. Dishwashers are energy efficient, and you often use a lot of hot water when washing dishes by hand. Instead, remember to fill up the dishwasher before you start it.

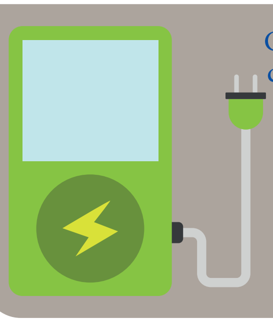
Can you program the termostat?

Can you heat the house a little before you get home from work? You can lower the temperature a little in the afternoon when the electricity is usually a little more expensive than during the day. Furthermore, maybe also keep warm by using the woodstove.

Some heat pumps can be programmed. Check if you can program yours for certain times of the day. Do you need a new water heater? New heaters are smarter and more energy saving.

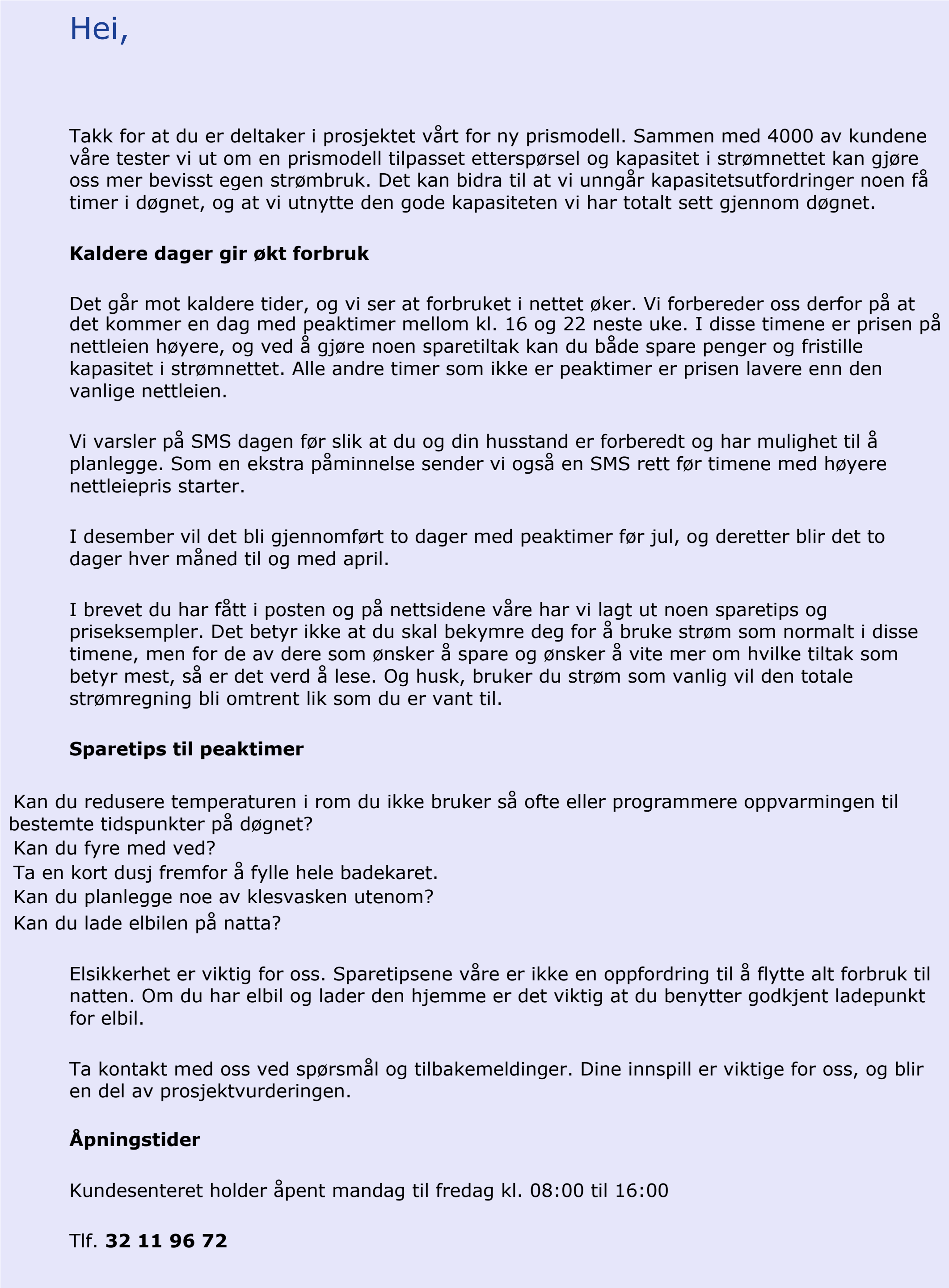


Charge your car during the night



An electric car draws much electricity when it charges. Feel free to charge at night when the rest of the power consumption is low.

C.3 Second contact: Email sent on December 6th, one week prior to the first CPP event



Hei,

Takk for at du er deltaker i prosjektet vårt for ny prismodell. Sammen med 4000 av kundene våre tester vi ut om en prismodell tilpasset etterspørsel og kapasitet i strømnettet kan gjøre oss mer bevisst egen strømbruk. Det kan bidra til at vi unngår kapasitetsutfordringer noen få timer i døgnet, og at vi utnytte den gode kapasiteten vi har totalt sett gjennom døgnet.

Kaldere dager gir økt forbruk

Det går mot kaldere tider, og vi ser at forbruket i nettet øker. Vi forbereder oss derfor på at det kommer en dag med peaktimer mellom kl. 16 og 22 neste uke. I disse timene er prisen på nettleien høyere, og ved å gjøre noen sparetiltak kan du både spare penger og fristille kapasitet i strømnettet. Alle andre timer som ikke er peaktimer er prisen lavere enn den vanlige nettleien.

Vi varsler på SMS dagen før slik at du og din husstand er forberedt og har mulighet til å planlegge. Som en ekstra påminnelse sender vi også en SMS rett før timene med høyere nettleiepris starter.

I desember vil det bli gjennomført to dager med peaktimer før jul, og deretter blir det to dager hver måned til og med april.

I brevet du har fått i posten og på nettsidene våre har vi lagt ut noen sparetips og priseksempler. Det betyr ikke at du skal bekymre deg for å bruke strøm som normalt i disse timene, men for de av dere som ønsker å spare og ønsker å vite mer om hvilke tiltak som betyr mest, så er det verd å lese. Og husk, bruker du strøm som vanlig vil den totale strømregning bli omtrent lik som du er vant til.

Sparetips til peaktimer

Kan du redusere temperaturen i rom du ikke bruker så ofte eller programmere oppvarmingen til bestemte tidspunkter på døgnet?
Kan du fyre med ved?
Ta en kort dusj fremfor å fylle hele badekaret.
Kan du planlegge noe av klesvasken utenom?
Kan du lade elbilen på natta?

Elsikkerhet er viktig for oss. Sparetipsene våre er ikke en oppfordring til å flytte alt forbruk til natten. Om du har elbil og lader den hjemme er det viktig at du benytter godkjent ladepunkt for elbil.

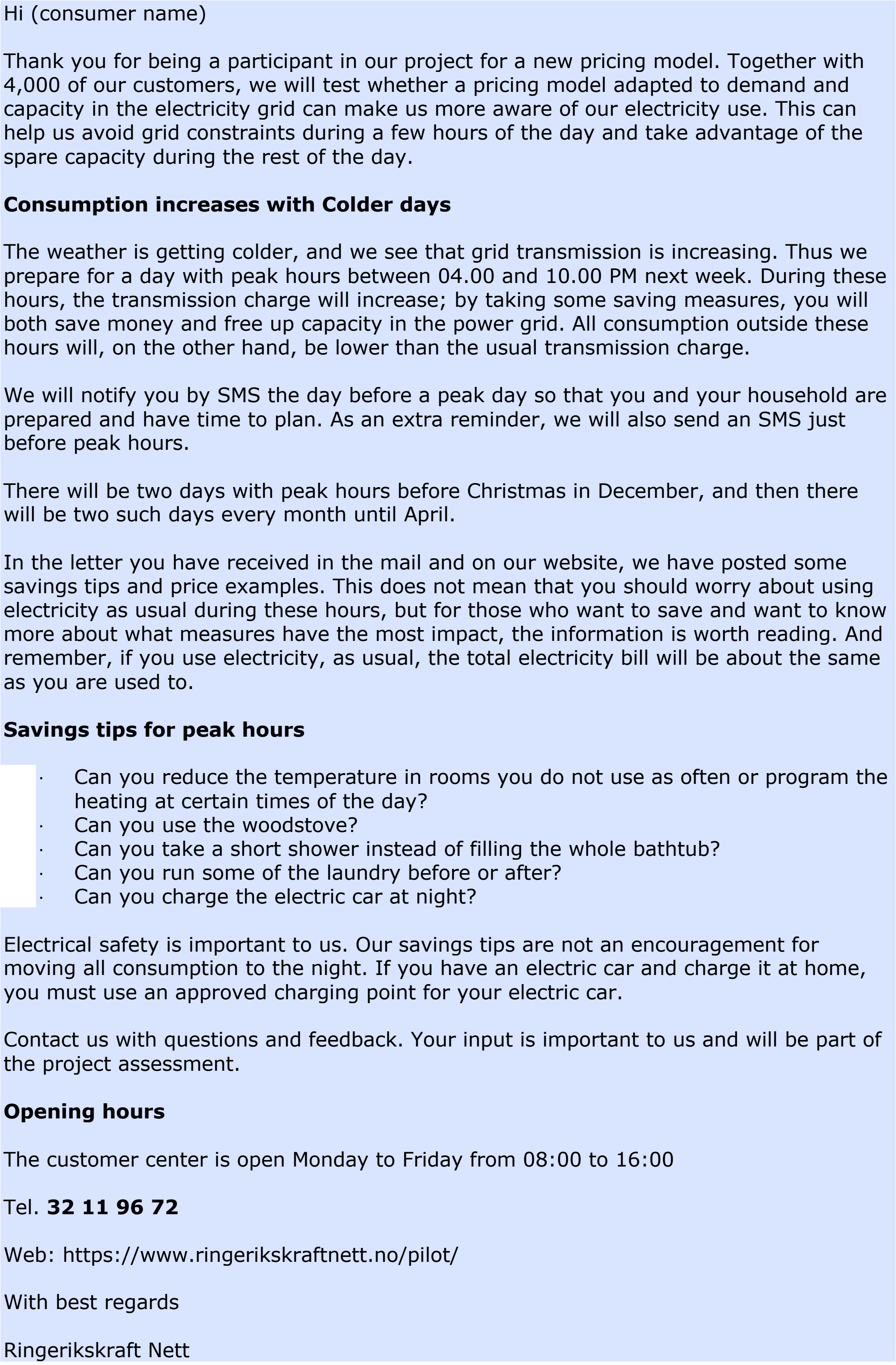
Ta kontakt med oss ved spørsmål og tilbakemeldinger. Dine innspill er viktige for oss, og blir en del av prosjektvurderingen.

Åpningstider

Kundesenteret holder åpent mandag til fredag kl. 08:00 til 16:00

Tlf. **32 11 96 72**

English translation



Hi (consumer name)

Thank you for being a participant in our project for a new pricing model. Together with 4,000 of our customers, we will test whether a pricing model adapted to demand and capacity in the electricity grid can make us more aware of our electricity use. This can help us avoid grid constraints during a few hours of the day and take advantage of the spare capacity during the rest of the day.

Consumption increases with Colder days

The weather is getting colder, and we see that grid transmission is increasing. Thus we prepare for a day with peak hours between 04.00 and 10.00 PM next week. During these hours, the transmission charge will increase; by taking some saving measures, you will both save money and free up capacity in the power grid. All consumption outside these hours will, on the other hand, be lower than the usual transmission charge.

We will notify you by SMS the day before a peak day so that you and your household are prepared and have time to plan. As an extra reminder, we will also send an SMS just before peak hours.

There will be two days with peak hours before Christmas in December, and then there will be two such days every month until April.

In the letter you have received in the mail and on our website, we have posted some savings tips and price examples. This does not mean that you should worry about using electricity as usual during these hours, but for those who want to save and want to know more about what measures have the most impact, the information is worth reading. And remember, if you use electricity, as usual, the total electricity bill will be about the same as you are used to.

Savings tips for peak hours

- Can you reduce the temperature in rooms you do not use as often or program the heating at certain times of the day?
- Can you use the woodstove?
- Can you take a short shower instead of filling the whole bathtub?
- Can you run some of the laundry before or after?
- Can you charge the electric car at night?

Electrical safety is important to us. Our savings tips are not an encouragement for moving all consumption to the night. If you have an electric car and charge it at home, you must use an approved charging point for your electric car.

Contact us with questions and feedback. Your input is important to us and will be part of the project assessment.

Opening hours

The customer center is open Monday to Friday from 08:00 to 16:00

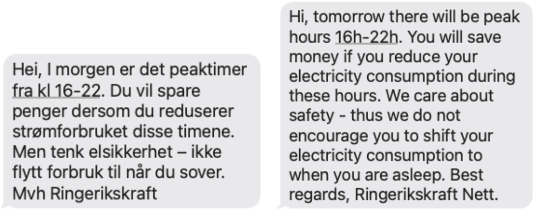
Tel. **32 11 96 72**

Web: https://www.ringerikskraftnett.no/pilot/

With best regards

Ringerikskraft Nett

C.4 SMS sent to the treatment group



Hei, I morgen er det peaktimer fra kl 16-22. Du vil spare penger dersom du reduserer strømforbruket disse timene. Men tenk elsikkerhet – ikke flytt forbruk til når du sover. Mvh Ringerikskraft

Hi, tomorrow there will be peak hours 16h-22h. You will save money if you reduce your electricity consumption during these hours. We care about safety - thus we do not encourage you to shift your electricity consumption to when you are asleep. Best regards, Ringerikskraft Nett.

(a) (b)

Figure C2 SMS sent one day ahead of a CPP event – (a): original, (b): English translation.