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IncentV2G - Analysis of the effect of incentives for efficient vehicle to grid integration

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Zusammenfassung

Um die Ziele der Schweizer Energiestrategie 2050 und die Schweizer Klimaziele zu erreichen, muss die Dekarbonisierung der Verkehrs- und Heizsysteme beschleunigt werden. Eine Möglichkeit, zu diesem Ziel beizutragen, ist der Ersatz von fossilen Brennstofftechnologien durch Technologien wie Elektrofahrzeuge und Wärmepumpen. Andererseits bringt die Elektrifizierung des Verkehrs- und Wärmesektors zusätzliche Herausforderungen mit sich, wie z.B. eine erhöhte Gesamtstromnachfrage und eine Verschärfung der Spitzenstromnachfrage, was die Aufmerksamkeit der politischen Entscheidungsträger erfordert.

In diesem Zusammenhang ist es wichtig, die Faktoren zu verstehen, die die Einführung von batteriebetriebenen Elektrofahrzeugen (BEVs) beeinflussen und sich auf die Nutzung von Ladestationen und Wärmepumpen auswirken. Dieses Forschungsprojekt zielt darauf ab, die Auswirkungen politischer Massnahmen zur Förderung der Einführung neuer BEVs zu analysieren und zu bewerten, wie ein Stromtarif mit direkter Laststeuerung (auf Englisch «Direct Load Control» oder «DLC») gefördert werden kann, um das Ladeverhalten und die Fahrzeugnetzintegration zu verbessern. Im ersten Teil der Studie untersuchen wir die Rolle von kantonalen Kfz-Steuerermässigungen und Kaufrabatten. Die Ergebnisse unserer Studie deuten darauf hin, dass 1) der Kaufrabatt fördert die Einführung von BEVs, obwohl die Auswirkungen relativ bescheiden sind und möglicherweise nicht kosteneffektiv sind 2) die Kfz-Steuerermässigung hat keinen wesentlichen Einfluss auf die Einführung von BEV. Die Ermässigung der Kfz-Steuer hat keinen signifikanten Einfluss auf die Einführung von BEVs. Eine mögliche Erklärung dafür ist, wie in Cerruti et al. (2023) gezeigt, die geringere Sichtbarkeit und das geringe Bewusstsein für Steuerermässigungen zum Zeitpunkt des Autokaufs. Um die Wirksamkeit von Steuerermässigungen zu erhöhen, ist es daher wichtig, Informationskampagnen über diese politische Massnahme durchzuführen. Im zweiten Teil der Studie untersuchen wir, wie sich die Bereitstellung von mehr Informationen über Stromtarife mit direkter Laststeuerung (DLC) und ein Vorabzuschuss auf die Einführung von DLC-Tarifen auswirken. Die Ergebnisse zeigen, dass diese beiden Massnahmen einen Einfluss auf die Akzeptanz dieses Elektrizitättarifs haben, auch wenn die Auswirkungen bescheiden sind. Der vorliegende Abschlussbericht fasst die Aktivitäten des Projekts zusammen und schliesst sie ab.

Résumé

Pour atteindre les objectifs de la Stratégie énergétique suisse 2050 et les objectifs climatiques suisses, il est nécessaire d'accélérer la décarbonisation des systèmes de transport et de chauffage. Une façon de contribuer à cet objectif est de remplacer les technologies liées aux combustibles fossiles par des technologies telles que les véhicules électriques et les pompes à chaleur. D'un autre côté, l'électrification du secteur des transports et du chauffage présente des défis supplémentaires, tels que l'augmentation de la demande globale d'électricité et l'exacerbation des pics de demande d'électricité, qui requièrent l'attention des décideurs politiques.

Dans ce contexte, il est important de comprendre les facteurs qui influencent l'adoption des véhicules électriques à batterie (BEV) et l'utilisation des stations de recharge et des pompes à chaleur. Ce projet de recherche vise à analyser l'impact des mesures politiques visant à promouvoir l'adoption de nouveaux BEV et à évaluer comment un tarif d'électricité à contrôle direct de la charge (en anglais « Direct Load Control » ou « DLC ») peut être promu pour améliorer le comportement de charge et l'intégration véhicule-réseau. Dans la première partie de l'étude, nous explorons le rôle des réductions

de la taxe cantonale sur la circulation des véhicules et des rabais à l'achat. Les résultats de notre étude suggèrent que 1) la subvention à l'achat favorise l'adoption des BEV, même si l'impact est relativement modeste et pourrait ne pas être économiquement avantageux 2) la réduction de la taxe sur la circulation des véhicules n'a pas d'impact significatif sur l'adoption des BEV. Comme le montrent Cerruti et al. (2023), cela peut s'expliquer par le fait que les réductions fiscales sont peu visibles et peu connues au moment de l'achat d'une voiture. Par conséquent, pour accroître l'efficacité des réductions fiscales, il est important de lancer des campagnes d'information sur cette mesure politique. Dans la deuxième partie de l'étude, nous examinons l'impact de la fourniture de plus d'informations sur les tarifs d'électricité avec contrôle direct de la charge (DLC) et d'une subvention initiale sur l'adoption des tarifs DLC. Les résultats montrent que ces deux mesures ont un impact sur le taux d'adoption de ce tarif spécial, bien que cet impact soit modeste. Ce rapport final résume et conclut les activités du projet.

Summary

In order to reach the goals of the Swiss Energy Strategy 2050 and the Swiss climate goals, it is necessary to accelerate the decarbonization of the transport and heating systems. One way to contribute to this objective is through the replacement of fossil fuel technologies with technologies such as electric vehicles and heat pumps. On the other hand, electrification of the transport and heating sector presents additional challenges, such as increased overall electricity demand and exacerbation of peak electricity demand, which requires attention from policymakers.

In this context, it is important to understand the factors influencing the adoption of battery electric vehicles (BEVs) and affecting utilization of the charging stations and heat pumps. This research project aims to analyze the impact of policy measures to promote the adoption of new BEVs and assess how a direct load control electricity tariff (DLC) can be promoted to improve charging behavior and vehicle-grid integration. In the first part of the study, we explore the role of cantonal vehicle circulation tax discounts and purchase rebates. The results of our study suggest that: 1) the purchase subsidy promotes the adoption of BEVs, although the impact is relatively modest and might not be cost-effective 2) The discount on the vehicle circulation tax doesn't have a significant impact on BEV adoption. A possible explanation for that is, as shown in Cerruti et al. (2023), the lower visibility and low awareness of tax discounts at the moment of purchasing a car. Therefore, to increase the effectiveness of tax discounts, it is important, to introduce information campaigns about this policy measure.

. In the second part of the study, we examine the impact of providing more information on direct load control electricity tariffs (DLC) and an up-front subsidy on adopting DLC tariffs. The results show that these two measures have an impact on the adoption rate of this special tariff, although the impact is modest. This final report summarizes and concludes the activities of the project.

Main findings

- Impact of policy measures on BEVs adoption:
  - Purchase subsidies help promoting the adoption of battery electric vehicles (BEVs), while circulation tax discounts have no clear effect. A possible explanation for that is the lower visibility of tax discounts at the moment of purchasing a car. Therefore, as shown in Cerruti et al. (2023), it is very important to introduce public campaigns to increase the level of policy awareness.
  - A simple back-on-the-envelope calculation indicates a low level of cost-effectiveness of the purchase subsidies because of a free-rider problem, i.e., the subsidy is also paid to individuals who would have bought a BEV in any case.
  - The low level of the cost-effectiveness of both measures suggests a rethinking of the policy measures to increase the adoption rates of BEVs.

- The diffusion of solar PV encourages BEVs adoption. This might be because people plan to charge the vehicle with self-produced electricity. Adoption of both solar PV and BEV might be also linked to characteristics such as environmental awareness, familiarity and openness to new technologies, and political orientation.

- Measures to increase the adoption of DLC tariffs:
  - The local electricity distribution utilities can increase the adoption of a direct load control (DLC) tariff by improving the awareness of this type of offer through an information campaign and/or by taking charge of the organization and installation cost of the DLC remote control system.
  - The effect of taking charge of the organization and installation cost is more important than the information treatment. However, one should keep in mind that the installation cost treatment is more expensive. Therefore, the information treatment based on video can be a valid strategy as well to promote the adoption of DLC tariffs.
  - Introducing a DLC tariff is unlikely to have a significant impact on the wholesale electricity price.

1 Contents

Abbreviations

BEVs: Battery Electric Vehicles

DLC: Direct Load Control

PV: Photovoltaics

WP: Working Paper

2 Introduction

2.1 Background information and current situation

In order to reach the goals of the Swiss Energy Strategy 2050 and the Swiss climate goalsin Switzerland, it is necessary to accelerate the decarbonization of the transport and heating systems. One way to contribute reaching this objective is through the replacement of fossil fuel technologies with technologies such as electric vehicles and heat pumps. On the other hand, electrification of the transport and heating sector presents additional challenges, such as increased overall electricity demand and exacerbation of peak electricity demand, which requires attention from policymakers.

In this context, is important to understand which factors contribute to the adoption of BEVs, which so far has been increasing in Switzerland but not at a sufficient level to foster decarbonization of the transport sector. At the same time, a better knowledge of how the presence of BEVs influences the electricity load is important as well, as information on charging behavior in Switzerland in scarce.

In Switzerland, various types of policy measures have been adopted to foster BEV adoption. Many cantons introduced a series of monetary incentives, such as discounts on the vehicle circulation tax and purchase subsidies. However, the effectiveness of these policies is still unclear: such incentives are given to all buyers of BEVs, and thus, they also benefit those who would have bought an electric car even without discounts or subsidies. This issue, known also as the free-rider problem, can increase the cost of these policies. The impact of these measures, and their cost-effectiveness, is still unclear in the Swiss context. Finally, the diffusion of rooftop solar PV can produce important synergies with BEV adoption, as owners of solar PV might be induced to buy a BEV with the intent to use the self-produced electricity to charge their electric car.

Battery electric vehicles are expected to play a major role in decarbonizing the transport sector and thereby the global economy. However, a recent study for California has shown that the largest share of consumers plugs their cars in and starts charging once they get home (Burlig et al. 2021). From a grid perspective, this will exacerbate the already existing evening demand peak and lead to additional capacity needs if not addressed accordingly. The electrification of the transport sector increases absolute electricity demand, but, if done well, can be achieved without such major increases in peak demand. To this end, well designed incentives to influence charging behavior that supports efficient vehicle to grid integration - even at high BEV adoption rates - are needed. Similarly, the diffusion of heat pumps poses similar challenges to the electricity system.

To address this issue, some Swiss electricity companies adopted a series of tariffs to reduce system load due to the diffusion of heat pumps and BEV charging stations. One type of these tariffs is known as direct load control (DLC) tariff, where a consumer receives a discount on the electricity bill while granting the possibility to the company to suspend the supply of electricity for heat pumps and charging stations during periods of high electricity demand. However, when not compulsory, the voluntary adoption of DLC tariffs remains rare. It is thus important to understand which factors can increase the adoption of DLC tariffs from Swiss households, and whether the low adoption is an information issue (which can be countered with better explanation of the tariff) or an incentive issue (which can be addressed by increasing the monetary incentive).

There is a large literature on the impact of monetary and non-monetary policies on the adoption of electric vehicles. There are also studies on the effect of cantonal incentives on the adoption of combustion engine energy efficient vehicles in Switzerland (Alberini et al. 2018, Cerruti et al. 2023), but not about the adoption of BEVs. In terms of charging behavior, there are initial studies on the impact of BEVs on domestic electricity consumption (Burlig et al. 2021), although most of them are not directly focused on Switzerland and do not consider the use of public charging stations.

Several studies in the literature analyzed the barriers to adopting a DLC tariff. Some studies analyze the role of distrust in the energy provider (Soland et al. (2018)), the role of loss of control on adopting a DLC

tariff (Bailey and Axsen (2015)). On another note, Soland et al. (2018) emphasize how DLC acceptance rates depend on the type of affected appliances.

On the pure dispatch modelling side, some studies are available (e.g. Schill and Gerbaulet 2015 for Germany) and show the benefits of cost-driven charging (i.e. dynamic pricing) over purely user-driven charging (charge when you get home as shown by Burlig et al. 2021). However, most modelling studies are based on assumptions on BEV charging behaviour, whereas our project will use empirical estimates. Research that integrates empirical analysis of incentives influencing adoption and charging behaviour of BEVs with models of the energy grid are rare, and none of them focused on Switzerland.

2.2 Purpose of the project

The general purpose of this project is to understand the factors influencing the adoption of battery electric vehicles (BEVs), and affecting utilization of the charging stations and heat pumps. This research project aims to analyze the impact of policy measures to promote the adoption of new BEVs and assess how a direct load control electricity tariff (DLC) can be promoted to improve charging behavior and vehicle-grid integration. In the first part of the study, we explore the role of cantonal vehicle circulation tax discounts and purchase rebates, and we analyze the effect in the residential sector of the presence of solar PV on the decision to buy a BEV. In the second part of the study, we investigate whether introducing two measures increases the subscription rates for a DLC tariff of owners of BEVs and/or of heat pumps.

2.3 Objectives

In this project, we aim to answer the following three main research questions:

RQ1. How do monetary policy measures and diffusion of solar PV influence the adoption of electric vehicles?

Various cantons in Switzerland provide incentives for the adoption of electric vehicles, such as rebates for the purchase of BEVs or discounts on the circulation tax for owners of such vehicles. At the same time, the diffusion of rooftop solar PV allowed households to dispose of self-produced electricity to charge their BEVs. Here, we aim to understand whether these factors contributed to the adoption of BEV.

RQ2. Which measures can improve the adoption of direct load control tariffs aiming to stabilize the electricity system?

Charging behavior, particularly timing and frequency, has important implications for the electricity grid's stability. To avoid the simultaneous occurrence of peak load and additional BEVs charging, various pricing strategies can be adopted, such as peak load pricing or direct load control (DLC) tariffs. However, up to date the adoption of DLC tariff remains low. To promote the adoption of DLC tariffs, it is possible to introduce 1) non-monetary measures, such as information on tariffs, and 2) monetary measures, such as discounts on electricity costs or installation cost of the device needed for the DLC tariff. We aim to explore the effectiveness of these measures in promoting a DLC tariff and how its adoption interacts with the electricity system's stability. Because the DLC tariff is also offered to owners of heat pumps, this analysis will also consider households that own this technology.

RQ3. What is the charging behavior of EV users?

The charging behavior of BEV users in Switzerland is largely unknown: while data on charging behavior through public charging stations is available, it is understood that currently most BEVs are charged at home, whereas data available for Switzerland is much more limited. Thus, our goal is to obtain data on charging behavior over hours of the day and days of the week, and to understand the diffusion of private home charging stations and the intention to install one in the future. This has important implications for

the stability of the grid, as a typical charging station has a higher power than a standard electric plug, and thus implies different patterns in terms electricity demand from BEVs.

2.4 Structure of the report

In this report, we summarize the findings of our research in two policy briefs. These policy briefs are based on academic research papers written for this project, which are available online.

The report is structured as follows: in the next section we present a short overview of the data and the methods used in our analysis. In section 4 we present the Policy Brief 1, where we summarize an analysis on the impact of cantonal circulation tax discounts, cantonal purchase subsidies, and the diffusion of solar PV, on the adoption of BEVs. In section 5 we include Policy Brief 2, where we present a summary of the analysis of the impact of two measures to promote DLC tariffs, drawing more general implications for the Swiss electricity system. In each policy brief, we indicated the link to the published working paper on which the brief is based. Moreover, in Policy Brief 2, the simulation of the effects of an increase in BEVs and heat pumps on the Swiss electricity market is based on a partial equilibrium model that is described in the Appendix of this report. In the Appendix, we present also selected findings from two surveys on the charging behavior of a sample of Swiss BEV owners. Finally, in sections 6, 7, and 8 we summarize our findings, list our collaborations and provide further direction of research.

3 Methodology and data

3.1 Methodology and data for Policy Brief 1

The empirical analysis supporting the finding of Policy Brief 1 is based on an econometric analysis. Such analysis is based on the estimation of a difference in differences model exploiting the variation in the introduction of the tax discounts and the purchase rebates across different cantons, and the variation in solar PV stocks over different municipalities. For this purpose, we estimate a model with the share of new BEVs for a given municipality in a given year as dependent variable, and as independent variables the indicators for the policies and the share of solar PV per building, plus various other municipality characteristics. We also include municipality- and year-fixed effects. The variables representing the policies are either dummy variables or the amount of monetary savings over the lifetime of the vehicles. In a second econometric model, we take into account the potential endogeneity of the solar PV diffusion, by instrumenting it with the 5-year moving average of solar radiation in a given municipality and year.

As our outcome of interest, we calculate the share of new yearly registered battery electric vehicles in each municipality using data from the Swiss Federal Office of Statistics from 2014 to 2021. For the diffusion of solar PV, we use data from the installation of solar PV with operating power of at least 2 kW between 2014 and 2021 from the Swiss Federal Electricity Commission. We then calculate 1) the ratio of the total number of solar PV installed in a year in a municipality over the total number of buildings in the municipality itself; 2) the ratio of the new solar PV capacity installed in a year in a municipality over the total number of buildings in the municipality itself.

Similarly, we also create two variables measuring the stock of solar PV: the average number of solar PV per building in each municipality in a given year and the average total solar PV capacity per building in each municipality in a given year. As for the other variables of interest, we obtain from cantonal legislation the years of implementation of the circulation tax discounts for both HEVs and BEVs, the circulation tax discounts only for BEV, and the purchase subsidies for BEV.

From the Swiss Federal Office of Statistics we obtain at the municipality level the share of women, the share of individuals from 0 to 19 years old, the share of individuals of 65 years old or more, and the

share of single-family homes. The Federal Electricity Commission also provides information on yearly electricity tariffs in each municipality. Finally, we get annual average data on surface solar radiation downwards from the ERA5-Land dataset, using the municipality centroid to assign radiation value to each municipality. Official statistics on the number of public charging station in each municipality are available only from 2020, so it was not possible to include this variable in our analysis. However, part of the effect of this variable is considered by our fixed effect model. For further details on data and methods, we refer to the working paper mentioned in Policy Brief 1.

3.2 Methodology and data for Policy Brief 2

The empirical analysis supporting the finding of Policy Brief 2 is based one survey and on two Randomized Control Trials (RCT). In a pre-phase of the study, we implemented an RCT using a stated choice approach to identify and verify the potential effectiveness of monetary incentives in promoting the adoption of a DLC tariff. For this purpose, we implemented a survey with 649 owners of electric vehicles in the Italian part of Switzerland. In this survey, we employed a contingent valuation protocol combined with an RCT to get information on the willingness to accept a DLC tariff under two scenarios. In the first scenario, participants were asked to cover the expenses for installing the remote control switch device needed for a DLC tariff, while in the second scenario, the cost of the device and its installation was covered by a subsidy offered by the local utility. We use then econometric methods to analyze the impact of the different scenarios.

After running the stated choice experiment, we decided to test the impact of an upfront subsidy for the organization and installation costs of the remote control switch device in a real context in promoting the adoption of a DLC tariff. For this purpose, we organized a second RCT with 1,500 customers owners of an electric vehicle and/or a heat pump, located in the Italian part of Switzerland, divided into three groups (a control and two treated groups). With the same RCT we also decided to test the impact of a second treatment, an information treatment, on the functioning of a DLC tariff with its advantages and disadvantages. This treatment, in line with the consumer choice literature on framing effects, aims to test if framing and communicating the same information in another way impacts the adoption of a DLC tariff. In the empirical analysis, we considered two outcome variables, i.e. the number of contacts to the energy provider to get more information on the DLC tariff and the number of new subscriptions of this tariff. To get information on the impact of the video and the installation cost treatment on the two main outcome variables, we estimated a logit and a linear probability model. For further details on data and methods, we refer to the working paper mentioned in Policy Brief 2.

4 Policy Brief 1 - Impact of monetary incentives and solar PV on the adoption of battery electric vehicles[1]

Davide Cerruti, Massimo Filippini and Jonas Savelsberg

Executive Summary

- Electrification of private passenger transport is crucial to lower carbon emissions and air pollution from the transport sector.
- To reach this goal, battery electric vehicles (BEVs) are an essential technology.
- Several cantons adopted monetary incentives to promote the adoption of BEVs.
- One common type of incentive is a discount on the annual cantonal circulation tax for BEVs. The other type is a subsidy on the purchase of a BEV.
- The present study investigates: 1) if the incentives in place are effective in promoting BEV adoption; 2) which of the two measures to promote BEVs is more effective; 3) whether the increased diffusion of rooftop solar PV induces households to buy a BEV.
- The empirical evidence shows that purchase subsidies help promoting BEVs while circulation tax discounts are not so effective. A possible explanation for that is, as shown in Cerruti et al. (2023), the lower visibility and low awareness of tax discounts at the moment of purchasing a car. Therefore, to increase the effectiveness of tax discounts, it is important to introduce information campaigns about this policy measure.
- When the market share of new BEVs is already a few percentage points high, purchase subsidies become less cost-effective in promoting the adoption of BEVs.
- The diffusion of solar PV encourages BEV adoption. This might be because people plan to charge the vehicle with self-produced electricity.

Outline

Electrification of private passenger transport represents a crucial milestone to reduce carbon emissions and air pollution from the transport sector. To accelerate this process, several central and local governments around the world introduced a series of monetary incentives for the purchase of battery electric vehicles (BEVs). The share of new BEVs increased significantly in the last few years: for instance, in 2016 the average share of new BEVs per municipality was 1.1%, while in 2021 it was 14.2%.

In many European countries, including Switzerland, two of the most common incentives are purchase subsidies and discounts on the annual vehicle circulation tax. The first policy is a lump sum transfer that reduces the purchase cost of a BEV. The second policy is a reduction of the annual tax every car owner

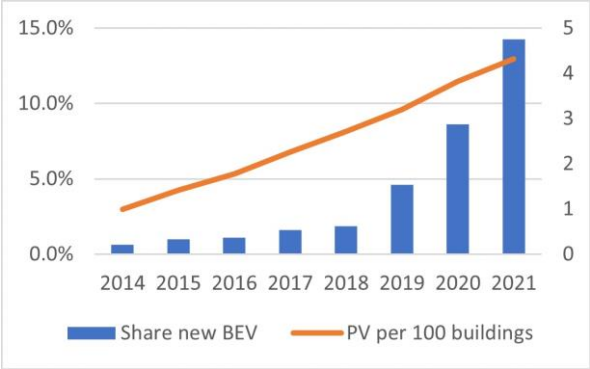
[1] The Swiss Federal Office of Energy finances this research under contract number SI/502345-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 1 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency. This policy brief is based on the following research paper: Davide Cerruti, Massimo Filippini and Jonas Savelsberg, Adoption of battery electric vehicles: the role of government incentives and solar PV, Working Paper Center for Economic Research at ETH (2023). Link: https://doi.org/10.3929/ethz-b-000648871

must pay to use the vehicle: this discount can be a percentage reduction on the base rate or a fixed amount reduction. In some cases such reduction is limited to the first few years after the purchase.

In Switzerland, these two types of incentives are typically adopted at the cantonal level and both involve the commitment from public institutions to invest public funds, either in terms of budgetary expenditures (purchase subsidies) or in terms of forgone tax revenues (tax discounts). In this study we aim to answer the following two questions: 1) are these measures effective? 2) which of the two measures is more effective, i.e. which type of incentive will increase the market share of BEVs the most for a given amount of money spent? In particular, the presence of free riders, i.e. individuals who would have bought a BEV even in the absence of incentives, implies that ineffective policies can have significant costs.

Another factor of interest is the diffusion of rooftop solar PV, which went from a total capacity of 1906 MW in 2017 to 3655 MW in 2021. One hypothesis is that the diffusion of solar PV might incentivize the adoption of BEVs, as households would charge their vehicle with self-produced electricity. As can be seen from Figure 1, the adoption of BEVs and solar PV increased dramatically between 2014 and 2021.

Figure 1: Comparison of share of new BEV and solar PV per 100 buildings between 2014 and 2021



Cantonal incentives for battery electric vehicles

The 26 cantons of Switzerland have considerable autonomy in setting up their own vehicle circulation tax and purchase subsidies for BEVs. We looked at cantonal legislation from 2014 to 2021 to understand which cantons adopted monetary incentives for battery electric vehicles.

The circulation tax is due every year and depends on one or more characteristics of the vehicle such as engine size, engine power, and weight. This baseline amount can be reduced (or increased) depending on the characteristics of the car, such as the presence of an electric engine.
We distinguish between four types of four monetary incentives to promote BEVs:

- Tax discounts (or increases) based on the vehicle energy label and/or CO_2 emissions per km.
- Tax discounts for hybrid vehicles and battery electric vehicles.
- Tax discounts for battery electric vehicles only.
- Purchase subsidies for battery electric vehicles.

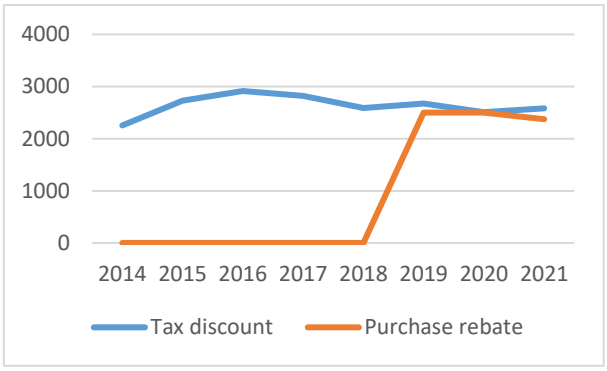
A canton can have one or more of these incentives. Tax discounts on energy labels and/or CO_2 emissions are applicable to all cars, while the other three measures are limited to hybrid and battery electric cars. In our analysis, we consider only incentives that apply specifically to BEVs.

During the period 2014-2021, 18 cantons had a tax discount in place for BEVs, and 4 cantons had a BEV purchase subsidy.

The role of cantonal incentives in promoting BEV adoption

To analyze the level of effectiveness of the policy measures introduced by the cantons we perform an empirical analysis based on the estimation of a regression model. For this purpose, we used yearly data from 2014 to 2021 at the municipality level on the share of new registrations of BEVs. Moreover, we have collected information on the amount and timing of the adoption of tax discounts and purchase subsidies for BEV in the various cantons. For circulation tax discounts, we also compute the amount of monetary savings for the lifecycle of a representative BEV. Figure 2 illustrates the average purchase subsidy and the average tax discount applied in the Swiss cantons that introduced these measures.

Figure 2: Average size of monetary incentives, CHF



In our regression analysis, we compare BEV market share in municipalities with and without the policy measures. In the analysis, we also consider other factors that can influence the adoption of BEVs, such as population, sociodemographic characteristics, consumer electricity price and share of single-family houses.

Our main findings are the following:

- The introduction of a purchase subsidy for BEVs increased the municipality share of new BEVs by 2.6 percentage points. Given that in the 2014-2021 period the average municipality share of BEVs for municipalities that never adopted one of the two policies examined was around 4.2%, the introduction of the purchase subsidy would increase this share to 6.8%.
- The effect of the introduction of a tax discount for BEVs is not statistically significant.

This difference in the impact may be due to a lower level of awareness of the circulation tax discount in comparison to the upfront subsidy that is more salient to the buyers of cars, as found out in the study by Cerruti et. al. (2023).

Given these results, we can perform a very rough back-on-the-envelope calculation. For example, in 2021 an increase in the purchase subsidy of 2500 CHF (corresponding to the average amount of the subsidy) will increase the number of new BEVs of approximately 2-3 units. Considering that the average number of newly registered BEVs in a representative municipality is already 15 units without subsidy, it would increase to 17-18 with a subsidy. In this situation, the total amount of subsidies in this municipality will be around 44,000 CHF. Therefore, the cost of increasing the number of BEVs by one unit would be around 16'000 CHF. The very high value is due to the fact that the upfront subsidy would be also paid to consumers that would have bought a BEV anyway.

If a representative gasoline car emits for 10 years (the average lifetime of a car in Switzerland) 13 tons of CO2, the subsidy will decrease the emissions only by this amount (extra BEV due to the subsidy). Therefore, the reduction cost per ton of CO2 is around 1200 CHF, which is a very high number. Because we do not observe an effect statistically significant from zero from the tax discounts, the costs related to such a policy would be even higher.

Of course, in this simple calculation, that are based on some assumptions, we are not considering all benefits such as the reduction of air pollution. Nevertheless, we show that the costs of these programs can be high when BEV adoption starts to rise, due to the presence of individuals who would buy a BEV in any case but still receive the incentive. When interpreting these results, one should keep in mind that the empirical analysis refers to a period of early stage of adoption of BEVs and with a limited number of cantons that introduced the tax discounts and the purchase subsidies. Our results are thus to be interpreted within this context. For instance, we cannot exclude that in the future the evaluation of these two policies might change with the evolution of the BEV market, the diffusion of public charging station and an increase of the cantons adopting these incentives.

Synergies between solar PV and BEV adoption

To analyze the relationship between BEV adoption and pre-existing solar PV capacity we perform an empirical analysis based on the estimation of a regression model. For this purpose, we use yearly data from 2014 to 2021 at the municipality level of the share of new registrations of BEVs and of the diffusion of solar PV, indicated either as number of solar PV every 100 buildings or as kW of installed solar PV every 100 buildings.

In our regression analysis, we compare BEV market share in municipalities with different levels of solar PV penetration. As for the analysis of cantonal incentives, we consider also other factors that can influence the adoption of BEVs, such as population, sociodemographic characteristics, consumer electricity price, and share of single-family houses.

Our main findings are the following:

- Adding 1 solar PV every 100 buildings would increase the municipality market share of new BEVs by 0.76 percentage points.
- Adding 10 kW of additional solar PV capacity to every 100 buildings would increase the municipality's share of new BEVs by 0.57 percentage points.

Policy recommendations

- The results of our study suggest that purchase subsides promote the adoption of BEVs, although the impact is relatively modest, while there is no clear impact from circulation tax discounts.

- The difference in the impact of the two policy measures may be due to the different levels of awareness among the buyers of these monetary incentives. Therefore, as shown in Cerruti et al. (2023), it is very important to introduce public campaigns to increase the level of policy awareness.
- The installation of solar PV has a positive influence on the adoption of BEVs. Therefore, subsidies that promote the adoption of solar panels may have also an impact on the adoption of BEVs.
- When the market share of new BEVs is already a few percentage points high, purchase subsidies become less cost-effective in promoting the adoption of BEVs. Conversely, when the share of BEVs is relatively low, as in the beginning of the period of our study, the policy might be cost-effective.
- Generally, there is a need to rethink the policy measures to further increase adoption rates of BEVs.

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Davide Cerruti, Massimo Filippini and Jonas Savelsberg, Adoption of battery electric vehicles: the role of government incentives and solar PV, Working Paper Center for Economic Research at ETH (2023).
Link: https://doi.org/10.3929/ethz-b-000648871

Davide Cerruti, Claudio Daminato, and Massimo Filippini. «The impact of policy awareness: Evidence from vehicle choices response to fiscal incentives.» Journal of Public Economics 226 (2023): 104973.
Link: https://doi.org/10.1016/j.jpubeco.2023.104973

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5 Policy Brief 2 - Impact of monetary incentives and information on the adoption of direct load control electricity tariffs[2]

Davide Cerruti, Massimo Filippini, Flora Marchioro and Jonas Savelsberg

Executive Summary

- The rise of electric vehicles and heat pumps will alter the electricity demand curve and create peak periods that could strain the power system. Electric utilities can use direct load control (DLC) tariffs to reduce the peak demand.
- With a DLC tariff, customers receive compensation for allowing the electricity provider to control the functioning of some large electrical devices, such as charging stations and heat pumps, during peak hours.
- For a DLC tariff, customers must install a remote-control switch system that costs around 300 CHF.
- The interest and acceptance rates of a DLC tariff among customers are generally low.
- The present study investigates whether giving the customers more information on a DLC tariff or taking charge of the organization and installation cost of the DLC remote control switch system increases the subscription rates for this special tariff.
- The empirical evidence shows that more information about a DLC tariff provided with a video and taking charge of the organization and installation cost are increasing the adoption of DLC tariffs, although these increases are modest.
- The effect of taking charge of the organization and installation cost is more important than the information treatment. However, one should keep in mind that the installation cost treatment is more expensive. Therefore, the information treatment based on video can be a valid strategy as well to promote the adoption of DLC tariffs.

Outline

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

[2] The Swiss Federal Office of Energy finances this research under contract number SI/502345-01 and has been conducted at the Centre for Energy Policy and Economics at ETH Zurich. This policy brief contributes to Work Package 2 of the project. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of the funding agency. This policy brief is based on the following research paper: Davide Cerruti, Massimo Filippini, Flora Marchioro and Jonas Savelsberg, Impact of monetary incentives on the adoption of direct load control electricity tariffs by residential consumers, Working Paper Center for Economic Research at ETH (2023). Link: https://doi.org/10.3929/ethz-b-000648877

The significant increase in electric vehicles will increase and modify the load curve of the electricity demand, especially during the late afternoon. A similar behavior in using heat pumps is also observed, i.e., heating services are more requested in the late afternoon and evening when most household members are home.

The change in the electricity demand and its load curve due to the increase of electric vehicles and heat pumps is expected to create periods of substantial peak demand that could determine problems for the electricity system, especially in balancing supply and demand. One approach to solve these problems is to invest in production and distribution capacity to satisfy the peak electricity demand. However, from an economic point of view, this solution can be inefficient and expensive because of the under-utilization of the production and distribution capacity during non-peak hours. An alternative approach to influence the shape of the load electric curve is to use pricing policies such as peak-load tariffs or direct load control (DLC) tariffs to incentivize consumers to move part of their demand from peak to off-peak periods.
Under DLC tariffs, customers are compensated for allowing their energy provider to control the functioning of certain large electrical devices, such as charging stations and heat pumps, during peak hours of the day through an installed remote control switch system. Although the prospects of DLC are encouraging, European customers' acceptance rates still need to be higher.
The present study aims to investigate whether introducing two measures increases the subscription rates for a DLC tariff. The two measures are 1) a video intervention providing more information on the functioning of a DLC tariff and 2) the electricity distribution utility takes charge of the organization and installation cost of the DLC remote control system needed for a DLC tariff.

Figure 1: Flyer about the DLC tariff, standard version (censored)

We analyzed the impact of these two measures in the context of the activities of a Swiss electricity company that, unsuccessfully, introduced in 2021 a DLC tariff for residential customers. From a methodological point of view, we use a Randomized Control Trial (RCT) with 1,500 customers, who were randomly assigned to one of these equally sized groups:

- A control group, that received the basic brochure of the DLC tariff that includes the standard conditions of this tariff (Figure 1);

- A video treatment group, who received a brochure that outlined the standard conditions for the tariff, plus an additional QR-code to access a video presenting the same information contained in the brochure but through a different format (Figure 4);
- An installation-cost treatment group who received a modified brochure outlining the tariff conditions but stated that the organization and installation cost for the DLC remote switch control system would be paid and managed by the utility provider.

We find evidence that both treatments positively impact the two outcome variables considered in this study, i.e., the number of contacts to the electricity company to get more information on the DLC tariff and the number of new subscriptions to the DLC tariff. These results confirm that the DLC tariff can be an interesting pricing policy to avoid electricity peak demand, reduce cost for the electricity system, and avoid overcapacity and electricity interruptions due to disequilibrium between demand and supply.

Charging habits for electric vehicles

To understand the charging behavior of owners of electric vehicles, we organized a first survey with 649 owners of electric vehicles (EVs) living in Ticino. The questionnaire used in the survey included several questions on the ownership and use of charging stations and electric vehicles. The results of this first survey on the usage of charging stations indicate that:

- Most of the participants in the survey can charge their car at home (82%)
- Around 40% of them own a charging station.
- Around 20% of the participants who do not own a charging station cannot install it because they don’t own the house.
- 40% of the participants that can charge at home but don’t have a charging station, plan on buying and installing one within 2 years maximum.

In the survey, we also asked the participants to fill in a diary on the charging behavior during a typical week in winter and a typical week in spring. To get this important information, we organized the survey twice, once in winter and once in spring.

The results on the charging habits show that:

- Around 20% of the respondents charge their cars at least 7 times a week for a mean charging length of 5.30 hours.
- As shown in Figures 1 and 2, responses confirm the existence of two peaks in the EV charging patterns. During a typical week, around 21% of respondents plugged in their vehicle in the morning from 8 until 10 AM, and 31% of respondents charged from 5 until 8 PM.

Figure 2: Charging start hours of electric vehicles, winter survey

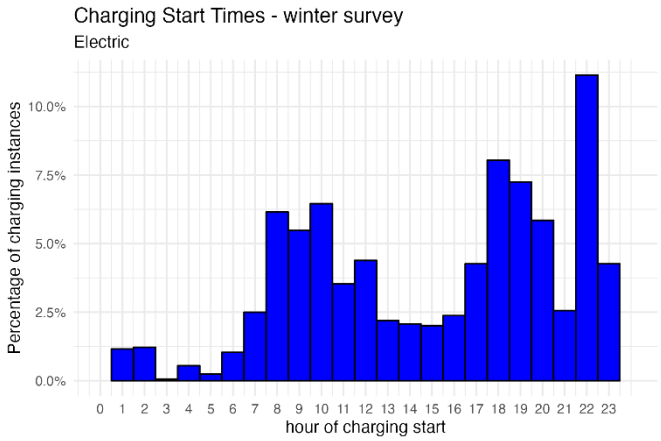
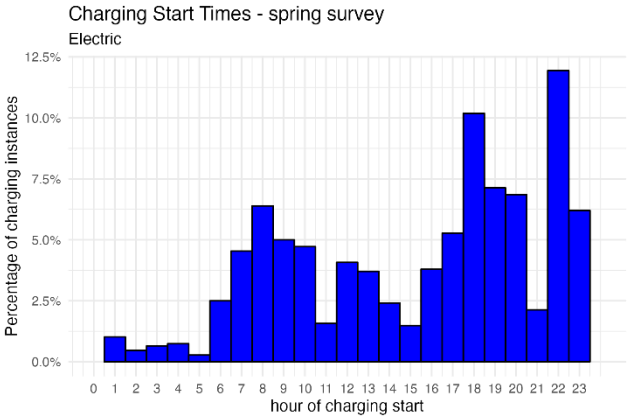


Figure 3: Charging start hours of electric vehicles, spring survey



In terms of usage habits of the EV, more than half of the respondents use their car daily to reach their workplace, while the percentage of respondents who claim to use their car daily for groceries or leisure reduces to 19% and 12%, respectively. On average, respondents who refer to their EV as the main vehicle in their household drive around 16,000 km/year.

Role of an upfront subsidy and more information

In a second survey, we organized a Randomized Control Trial to analyze the impact of the two measures (information and installation cost) on the number of adoptions of a DLC tariff. Moreover, because the period of observation of the effects of these two measures was relatively short (between April 18th and June 30th), we also consider as outcome variable the number of contacts of clients to get more information on the DLC tariff. We believe that this is also an interesting outcome variable because in such a short time it is not always easy to decide to change a tariff.

Figure 4: Flyer about the DLC tariff, with QR-code for the video (censored)

The descriptive results of the RCT experiment indicate that:

- After receiving one of the three brochures, 121 clients contacted the electricity company to get more information on the new tariff, and 34 to directly subscribe to the new tariff.
- Among the 121 clients who contacted the energy provider, approximately 53% of them belonged to the group that received an upfront subsidy to cover the installation cost, while around 28% were linked to the video treatment group.
- Among the 34 clients who decided to adopt the new tariff, approximately 61% of them belonged to the group that received an upfront subsidy to cover the installation cost, while around 32% were linked to the video treatment group.
- Regarding the video treatment, most of the treated clients who contacted the electricity company or adopted the DLC tariff watched the video.

The econometric results show that:

- The explanatory video increases contact and subscription rates by around 3 percentage points and 2 percentage points, respectively.
- Even though the video brochure has generated more contacts and subscriptions compared to the standard brochure, statistically, the impact of the video does not seem to be consistently significant across all analyzed models.
- Taking charge of the organization and installation cost of the DLC remote control system has generated approximately 9 additional contacts and 5 additional subscriptions for every 100 brochures sent, compared to the standard brochure.
- Generally, the impact of the two treatments is modest.

Policy recommendations

- Electric utilities can use direct load control (DLC) tariffs to reduce the peak demand.
- To increase the number of customers that accept to subscribe to a DLC tariff, electricity distribution companies can introduce: 1. an annual discount on the peak price of at least 2 cents

per kWh; 2. Organize an information campaign on the functioning of this type of tariff using different media approaches such as video. 3. Take charge of the organization and installation cost of the DLC remote control system.

- Based on empirical evidence, it appears that the impact of certain measures (video treatment and installation cost subsidy) to increase adoption of DLC tariffs for electric vehicles and heat pumps is modest.
- The effect of taking charge of the organization and installation cost is more important than the information treatment. However, one should keep in mind that the installation cost treatment is more expensive. Therefore the information treatment based on video can be a valid strategy as well to promote the adoption of DLC tariffs.
- As an alternative to these measures, owners of these vehicles and pumps could be subject in a mandatory way to a DLC tariff. This strategy has been already implemented by some Swiss electric utilities. Nonetheless, this might come at the expense of decreased consumer welfare, as it could affect overall comfort.
- As a feasible alternative, we suggest defaulting eligible clients into DLC tariffs while allowing them the option to opt-out. This approach is seen as the most economically viable and efficient solution for managing increased electrification while maintaining consumer flexibility.

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Davide Cerruti, Massimo Filippini, Flora Marchioro and Jonas Savelsberg, Impact of monetary incentives on the adoption of direct load control electricity tariffs by residential consumers, Working Paper Center for Economic Research at ETH (2023). Link: https://doi.org/10.3929/ethz-b-000648877

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6 Conclusions

As discussed in Working Paper 1 and summarized in Policy Brief 1, we show that among the two main monetary incentives used by cantons to promote electric mobility, purchase rebates seem to have a higher impact than circulation tax discounts. A possible reason for this result is the lower visibility of tax discounts by prospective vehicle buyers. Both measures have, nevertheless a high cost per additional BEV adopted, due to the presence of consumers who benefit from the incentives but would have bought a BEV in any case. For this reason, we suggest further examination on the best instrument to incentivize the adoption of EV. We also show that the diffusion of solar PV is a factor promoting the diffusion of BEV, probably because individuals plan to charge their BEVs with self-produced electricity. Thus, policy measures incentivizing the adoption of solar PV might have an additional effect of increasing EV adoption as well.

In Working Paper 2, summarized in Policy Brief 2, we show that electric distribution utilities can use direct load control (DLC) tariffs to reduce the peak demand. Further, to increase the number of customers that accept to subscribe to a DLC tariff, electricity distribution companies can introduce: 1. an annual discount on the peak price of at least 2 cents per kWh; 2. Organize an information campaign on the functioning of this type of tariff using different media approaches such as video; and take charge of the organization and installation cost of the DLC remote control system. Moreover, based on empirical evidence, it appears that the impact of these measures to increase the adoption of electric vehicles and heat pumps is only modest. As an alternative, owners of these vehicles and pumps could be subject in a mandatory way to a DLC tariff. This strategy has been already implemented by some Swiss electric utilities. Nonetheless, this might come at the expense of decreased consumer welfare, as it could affect overall comfort. As a feasible alternative, we suggest defaulting eligible clients into DLC tariffs while allowing them the option to opt-out. This approach could be an economically viable and efficient solution for managing increased electrification while maintaining consumer flexibility. Finally, introducing a DLC tariff is unlikely to have any impact on the wholesale electricity price, at least with a moderate number of BEVs and heat pumps.

7 Outlook and next steps

In the next two months we will organize a workshop with policymakers and industry partners, in particular, the managers of the Swiss electric utilities.

An important further goal of future research is to explore the effectiveness of other types of incentives that public authorities can introduce to promote the adoption of BEVs, such as subsidies for the installation of public charging stations, and information campaigns to correct potential consumers' bias about the characteristics of BEVs (fuel savings, battery range, charging needs).

Along with BEVs, heat pumps are another technology that might pose significant challenges to the stability of the Swiss electricity grid. Thus, it would be important to analyze from a technical and economic point of view the usage behavior of this technology and assess further the impact of monetary and non-monetary measures to influence their usage. In this context, could be interesting to explore as well the behavior of the usage of BEVs and heat pumps for households that own also a rooftop solar PV.

Currently, most BEV adopters appear to be individuals with the possibility to charge their vehicle at home. The next generation of BEV owners will likely live in multi-family households and apartments without such a possibility. Therefore it would be important to collect information on the charging behavior of this crucial group of future owners.

8 National and international cooperation

Within the project, we collaborated with the following institutions:

- Aziende Industriali Lugano
- Enertì – Emotì
- Energie 360

Conference presentations:

- Empirical Methods in Energy Economics, Yale University, New Haven, United States, 9-10 January 2023
- International Transport Economics Association Annual Conference, University of Cantabria, Sandander, Spain, June 14-16 2023
- FSR Workshop on "Future Electricity Tariffs", European University Institute, Florence, Italy, 21-22 June 2023
- 1st Swiss workshop on Environmental, Resource and Energy Economics, ETH Zürich, 10 November 2023

Invited seminar presentations:

- VATT Institute for Economic Research, Helsinki, Finland, 24 November 2022
- IdEP-USI Brownbag Seminars, Università della Svizzera Italiana, Lugano, 30 May 2023

9 Publications

Adoption of battery electric vehicles: the role of government incentives and solar PV,

Abstract:

Electrification of the private passenger transport sector is a fundamental milestone in reducing global carbon emissions. To reach this goal, several governments introduced a series of incentive programs to encourage the adoption of battery-electric vehicles (BEVs). Two of the most widespread policies to incentivize the adoption of BEVs are discounts on the annual vehicle circulation tax and purchase rebates. This paper analyzes the causal relationship between introducing these two policies and adopting battery-electric vehicles (BEVs) in Switzerland. We also examine the effect of the diffusion of rooftop solar PV on the adoption of BEVs. We find that purchase rebates for BEVs positively affect their adoption, while the discount on the circulation tax has a minor or no effect. However, the cost-effectiveness of both policies remains low because of a free-riding problem, i.e. all buyers of a BEV are entitled to the incentives, including those who would have bought a car even in their absence. The diffusion of solar PV facilitates the adoption of BEVs.

Working Paper: Davide Cerruti, Massimo Filippini and Jonas Savelsberg, *Adoption of battery electric vehicles: the role of government incentives and solar PV*, Working Paper Center for Economic Research at ETH (2023), available at: https://doi.org/10.3929/ethz-b-000648871

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

Abstract:

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

Working Paper: Davide Cerruti, Massimo Filippini, Flora Marchioro and Jonas Savelsberg, *Impact of monetary incentives on the adoption of direct load control electricity tariffs by residential consumers*, Working Paper Center for Economic Research at ETH (2023), available at: https://doi.org/10.3929/ethz-b-000648877

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11 Appendix :

A. Survey on charging behavior and characteristics of EV owners

B. System impacts of BEVs and heat pumps integration in Switzerland