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# **Reducing Swiss household energy demand**

## Modelling and assessing non-monetary incentives (information and social norms)

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**All contents and conclusions are the sole responsibility of the authors.**



## Zusammenfassung

In diesem Projekt untersuchen wir welchen Einfluss soziale Normen und Informationen auf die Energienutzung von Haushalten haben, wobei wir die Heterogenität von Haushalten besonders berücksichtigen. Zu diesem Zweck nutzen wir Befragungsdaten, die im Rahmen des SCCER CREST erhoben werden (SHEDS Daten) und entwickeln ein agenten-basiertes Modell. Dieses Modell beinhaltet unterschiedliche Typen von miteinander interagierenden Haushalten und ermöglicht es damit, individuelle Effekte konsistent zu aggregieren und auf Haushaltstypen zugeschnittene Interventionen zu analysieren. Bis jetzt haben wir die allgemeine Analyse der Befragungsdaten abgeschlossen, sowie die spezifische Auswertung der Elektrizitäts- und Mobilitätssteile vorangetrieben; wir haben ein Experiment designt und durchgeführt, um zusätzliche Daten zu gewinnen; und wir haben für Elektrizität und Mobilität ein agentenbasiertes Modell aufsetzen können, das detaillierte Prozesse für die Diffusion von Informationen und Normen beinhaltet. Unsere bisherigen Ergebnisse zeigen, dass soziale Normen und Informationen individuelles Verhalten im Energiebereich beeinflussen, sowohl in Bezug auf Investitions- als auch auf Nutzungsverhalten und dass Interaktionen mit Preissignalen teilweise wichtig sind. Allerdings bestehen erhebliche Unterschiede im Einfluss sozialer Normen und Informationen für verschiedene Arten der Energienutzung (Wärme, Strom, Mobilität) und für verschiedene Haushaltstypen. Somit scheint die grundlegende Idee des Projekts – die Analyse von Interventionen, die auf Haushaltstypen und Arten der Energienutzung abgestimmt sind – hochgradig relevant zu sein.

## Résumé

Dans ce projet, nous étudions l'influence des normes sociales et de l'information sur l'utilisation de l'énergie par les ménages, en mettant un accent particulier sur l'hétérogénéité des ménages. À cet effet, nous utilisons des données d'enquête collectées dans le cadre du SCCER CREST (données SHEDS) et développons un modèle multi-agents couvrant différents types de ménages en interaction afin de pouvoir agréger de manière cohérente les effets individuels et d'évaluer les effets d'interventions politiques adaptées. Jusqu'à présent, nous avons terminé l'analyse générale des données de l'enquête, élaboré une expérimentation des choix (choice experiment) pour obtenir des données supplémentaires et développé deux prototypes du modèle multi-agents (électricité et mobilité) ainsi qu'un modèle de diffusion de l'information. Les résultats obtenus jusqu'à présent montrent que les normes sociales et l'information influent sur les comportements individuels liés à l'énergie, tant en ce qui concerne les investissements que l'utilisation, et ont parfois des interactions avec des incitations de prix. L'influence des normes sociales et l'information varie fortement selon les types d'utilisation de l'énergie (chauffage, électricité, mobilité) et varie selon les types de ménage. Ainsi, l'idée principale du projet, l'évaluation des interventions adaptées aux types de ménages et aux types d'utilisation de l'énergie, semble être très pertinente.



## Summary

In this project, we investigate the influence of social norms and information on household energy use with a particular focus on household heterogeneity. To this end, we use survey data collected in the context of the SCCER CREST (SHEDS data) and develop an agent-based model covering different types of interacting households for being able to consistently aggregate individual effects and for assessing the effects of tailored policy interventions. So far, we have completed the general analysis of the survey data, designed a choice experiment to gain additional data, and developed two versions of the agent-based model (electricity and mobility) as well as a model of information diffusion. Results so far show that social norms and information influence individual energy-related behavior, both with regard to investments and with regard to usage and interact to some extent with price incentives. The influence of social norms and information varies strongly for different types of energy use (heating, electricity, mobility) and differs between household types. Thus, the main idea of the project, the assessment of interventions tailored to specific types of households and types of energy use, appears to be highly relevant.



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## Abbreviations

ABM – Agent-based model

EICom – Federal Electricity Commission

FEDRO – Federal Roads Office

FSO – Federal Statistical Office

GA – General Abonnement

MoT – Mode of Transport

RA – Regional Abonnement

SBB – Schweizerische Bundesbahnen

SFOE – Swiss Federal Office of Energy

SHEDS – Swiss Household Energy Demand Survey



# 1 Introduction

## 1.1 Background information and current situation

Reducing energy demand is central to achieve the Swiss Energy Strategy 2050 targets. To achieve a reduction of energy consumption per capita, influencing household energy demand will be important, as households decide about a substantial part of residential and mobility-related energy use (about 2/3 of final Swiss energy consumption). Household behaviour can be influenced by monetary incentives but also by individuals' information levels, perceptions of, and responsiveness to social norms. These so-called "soft incentives" could be crucial for improving energy efficiency (Alcott, 2011).

Two important aspects need to be considered when focusing on soft incentives: (1) the aggregate effects and (2) tailored interventions that are specific to types of households or types of energy use. To do that, two connected tasks are essential: (a) assessing the effects of soft incentives on behavior and on the performance of monetary instruments on the *household level* and (b) aggregating these effects to the *national level*. Both are non-trivial tasks that require substantial research.

On the *household level*, most of the existing empirical research focuses on monetary incentives (see, for example, Alberini et al., 2013; Alberini and Bareit, 2016; or Bruderer et al., 2015). Studies on non-monetary incentives usually focus on specific measures and thus provide rather fragmented information (e.g., Goldstein et al., 2008; Griskevicius et al., 2010; or Degen et al., 2013). Furthermore, results from the Swiss Household Energy Data Survey (SHEDS) suggest that there is substantial heterogeneity among household types and among different types of energy use that could be (but, so far, has not been) used to tailor soft incentives to particular groups or types of energy use.

On the *aggregate level*, assessing total effects of soft incentives requires novel tools, as these incentives are based on interactions among households (social norm formation, information diffusion). An assessment of aggregate effects requires tools that capture not only the effects of information and social norms on household behavior but also describe how changes in behavior or policy measures influence such norms and the availability of information. Currently, such tools do not exist.

## 1.2 Purpose of the project

In this project, we provide a model-based assessment of the *aggregate* effects of social norms and information on energy use (in the domains of mobility, electricity demand and space heat) that takes into account different types of households (population segments) and their interactions and that is based on a detailed empirical assessment of the effects of social norms and information on the *individual* level.

On the individual level, we use survey data to analyze the relation between energy literacy and the responsiveness to social norms and detailed measures of energy use (in the aforementioned domains) for different types of households. On the aggregate level, an agent-based model is developed that uses the empirical results to describe and aggregate individual behavior, taking into account feedback effects from changes to social norms and information diffusion. Finally, both the empirical and the model-based analysis will be crosschecked with a different data source (municipal data) for mobility and electricity usage.

The project is embedded in SCCER CREST and helps to advance its research line on the transfer of insights on consumer behavior into the design, modeling, and evaluation of energy policies and regulations. It also complements the development of a detailed demand-side model within CREST. The project utilizes the basic structure of the model developed in CREST (description of different types of energy use and different types of households) but extends it to cover information and social norms in addition to the standard policies (such as prices) that is part of the basic CREST model.



### 1.3 Objectives

In detail, we first investigate (based on survey data) how strongly perceived pressure from social norms, energy literacy, and energy prices influence energy-related behaviour and whether these influences differ among different socio-demographic groups (clusters<sup>1</sup>). We expect to see different levels of influence between clusters, which would indicate that there might be a benefit of tailoring policy interventions to particular subgroups of the Swiss population (e.g., using norm-based campaigns for rural areas and information-based campaigns for urban areas).

Second, we use this analysis to build a model that captures feedback effects (such as changing social norms or a diffusion of information in networks). This enables us to simulate aggregate effects of policy interventions. We expect to be able to show that a) tailoring policies becomes even more advantageous in an aggregate setting, as non-targeted groups will be influenced via such feedback effects by targeted groups; and b) that aggregate effects differ substantially from upscaled individual effects, indicating that a dynamic model is indeed essential to assess aggregate outcomes.

Finally, we will use a second data source to cross check our findings and will provide a simplified model version for use in other simulation models.

## 2 Procedures and methodology

The project consists of two parallel streams. Workstream 1 “Empirical Analysis” analyses the influence of information and social norms on different types of energy use for different types of households, using the CREST household survey SHEDS as well as municipal data on mobility and electricity use. Workstream 2 “Agent-based modelling” develops an agent-based model of energy consumption of different household types and of the interactions stemming from information diffusion and the formation of social norms.

The empirical insights resulting from the analysis of SHEDS are used to initialize and calibrate the agent-based model. Also, municipal data that is gathered in Workstream 1 will serve as validation for the model predictions.

### 2.1 Workstream 1 “Empirical Analysis”

The empirical analysis consists of two steps. In Task 1.1 “Information and Social Norms”, survey data is used to analyse the influence of social norms and information on individual energy use (electricity, heating, mobility) for different clusters of households (five population segments by age and the place of living). Task 1.2 combines additional survey data and municipal data for a more detailed analysis of energy-relevant behaviour in the three sectors and also includes the discrete choice experiment (see below).<sup>2</sup>

Task 1.1 was (almost) completed end of 2018, the remaining work consisted of analysing the additional data from the 4<sup>th</sup> wave of SHEDS and adding a more detailed analysis of cross-effects of prices and soft incentives.

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<sup>1</sup>We distinguish five household segments according to the place of living and the age group of adult household members. Cluster 1 subsumes the young urban population, Cluster 2 the young rural, Cluster 3 are the middle-aged urban households, Cluster 4 the middle-aged rural, and Cluster 5 are the seniors (urban and rural).

<sup>2</sup> Note that originally Workstream 1 consisted of three tasks. When extending the timeline to the end of 2021 this year, we merged Tasks 1.2 and 1.3. For more information, see Fig. 2 in Section 5.



During the past year, we have decided to add an additional source of data to gain insights into a highly relevant part of individual behaviour (relocation as a major life decision) that would not be accessible otherwise. In the 2019 wave of SHEDS, we have implemented a randomized controlled discrete choice experiment to test two soft-measure treatments in the situation of a home relocation. The choice setting of the home relocation allows us to gain insights into the decision-making process, when choices have a potentially large impact on the future energy consumption of a household. By choosing a home with certain characteristics, a path for the energy consumption related to that home is set. The size of the living space, the energy efficiency and the location of a home lock in a substantial share of the energy demand. The larger the living space the more heating is required. An energy efficient home, which is built according to a high standard with regard to energy efficiency (e.g. Minergie), consumes *ceteris paribus* less energy than a home with a low standard. These two characteristics cover important aspects of electricity and heating demand of a home. A third home-related aspect that affects energy demand for mobility is the location of the home. The distance between the home and places that are visited on a regular basis, such as work or caretaker responsibilities, influences the energy required for such trips independently of the chosen mode of transport.

As such relocations occur too rarely to be readily observable in a mid-scale survey, such as SHEDS, a different method is necessary. We designed a choice experiment that places respondents in a fictive relocation situation and included several treatments to analyze how the relocation decision might be influenced by the soft measures considered in this project. The experiment was designed in collaboration with other CREST researchers (see Section 6).

As part of Task 1.2 and in order to check our results from the SHEDS data, we have also started to gather municipal data as a second data source. This municipal data is based on observed (not stated) behavior and a completely independent data source. We have collected three types of data: (i) socio-demographic and economic characteristics, (ii) mobility behavior and (iii) proxies for social norms and information. The descriptive statistics are presented in the next section.

The Swiss Federal Statistical Office (FSO) has provided most of the socio-demographic and economic data. Using the municipality characteristics regarding age distribution and typology, we will apply the same manual segmentation approach as in the previous analysis on the SHEDS data. Here, the age dimension of the municipality is the age partition that has the highest percentage. Regarding the mobility data, we have collected information on both public and private transports. The Schweizerische Bundesbahnen (SBB) and the Swiss Federal Roads Office (FEDRO) have provided information on the public transport and private transport behavior, respectively.

As detailed individual information is not available in the municipal data, one of the challenges is to find appropriate proxies for social norms and information. Regarding social norms at the municipal level, we have considered four indicators as proxies for social norms. One indicator is based on voting behavior during national, cantonal and local elections. A second indicator considers party membership in each municipality. As a third indicator, we intend to use municipal data on environmental ballots. This indicator is an alternative proxy of green ideology and is less influenced by elections events. The fourth indicator focuses on green business. A green business is a socially and environmentally responsible business that provides green products or services and that operates in ways that solve rather than cause social and environmental problems. Green people are more likely to move to a municipality with a higher rate of green business or green businesses would be more likely to locate near green community (Kahn, 2007)

FSO has provided data on the voting behavior during elections (first indicator) and environmental ballots (third indicator). For the moment, we have not been able to have access to the information related to party membership in each municipality (second indicator). For the green business data (fourth indicator), we have selected the major retailers (Coop, and Migros) and have sent requests to have access to their



data on green products sales per municipality. Due to data privacy, we were not able to get the information at the municipal level. As an alternative, we have decided to collect the green business information in each shop. Due to budget and time constraints, we have chosen online data collection and have selected Migros shops, as their information is available online.

For time consistency, the online data has been collected in two rounds. The first and second rounds took place in February-March 2019 and June 2019, respectively. We have considered two types of organic products (eggs and bread) as they are the most bought in Switzerland (Bio Suisse, 2019). In each Migros shop, we have checked online if the product is available. In addition, whenever we have the information, we have checked how many of the products are still available in the selected shops.

In order to be consistent with the argument of using green business as a proxy for social norms, we have extended this indicator to municipalities where a Migros shop is not available. Even though a municipality does not have a Migros shop, someone living in a close municipality with a Migros shop can have access to the green products depending on the distance. Consequently, for any municipality without Migros shops, we have calculated the weighted average of the availability or quantity of selected organic foods using the distance to the three closest Migros shops.

As a proxy for information (energy literacy), we have planned to construct an index related to media coverage (including both local and national newspapers) of topics that match with the items we used to construct energy literacy at the household level (energy label, costs of electricity, energy prices, energy conservation, etc.). Alternatively, we have also planned to use observed competences (e.g., a switch to LED lighting) in the case the data is available. Due to the complexity of linking the information contained in newspapers to a municipality, we have proceeded for now with the second option. However, we are still exploring the first option in order to find a good data on media coverage. We have collected online information on LED light bulbs in Migros shops, as described above. The information includes both the availability and quantity of the LED light bulbs in each shop. We have also extended the information to the other municipalities without Migros shops following the same approach as described above.

The proxies for information and social norms will be used in Task 1.2 as independent variables together with socio-demographic and economic characteristics. As dependent variables we will use car registration data (number of cars, energy efficiency) and travel cards (number of abonnement general, half fare card and regional card). Although we expected to get panel data for the mobility, socio-demographic and economic characteristics at the municipal level, the proxies for information and social norms that we have collected are not panel data. Furthermore, due to the short temporal dimension of the SHEDS data (2016-2019), we have decided to use it as pooled data. Therefore, a municipal panel data would not be useful to crosscheck the results from the SHEDS data and the predictions from the ABM. Thus, the empirical analysis at the municipal level will for a substantial part be based on a cross-sectional data.

With regard to municipal electricity data, we are currently trying to gain access to data on average household electricity consumption on the municipal level. In addition, we will use the municipal data as a second data source to have a closer look at the interaction of monetary and non-monetary incentives.

## 2.2 Workstream 2 “Agent-based modelling”

The model-based analysis in Workstream 2 consists of two tasks. In Task 2.1 “Design and Calibration”, an agent-based model (ABM) of Swiss household energy demand is developed that describes the behaviour of consumer agents that are influenced by social norms, information and policy interventions. The model describes feedback effects arising from changing social norms and information diffusion and



differentiates between different household clusters (population segments). It thus can provide information on aggregate effects of policy interventions and on the effects of interventions tailored to specific household types. In Task 2.2 “Application and Approximation”, the model will be applied to assess a range of interventions and an approximate model will be derived that is sufficiently simple for being used in general equilibrium models.

During the past year, we have re-organized some of the original milestones to adjust to the new time-schedule until mid/end 2021. (For details on the milestones, see Section 5.) We also had to accommodate another swap in our team: Dr Prudence Dato reduced working on the ABM and instead focused on the municipal data. Dr des. Moritz Schillinger joined our modelling team in October such that we are at full strength again.

Within the general scope of the ABM, i.e., equally relevant for electricity, mobility and heat, we have developed further segments for the dynamics of the model. Most prominently, we have set up a structure for information diffusion and norm-fuelled behavioural changes of agents. These occur at two levels: through conversations between agents or through institutional campaigns.

For the electricity ABM, we have agreed on the detailed set of channels and specifications that we are going to use to start the calibration. For further details, see Sections 4.2 and 5.2.

Similar to the electricity ABM, the ABM in the mobility sector considers a decision-making process that includes both investment decisions (travel cards, passenger cars) and usage decisions (preferred mode of transport for work and leisure activities). The challenge here is to model a decision tree that has three levels of decisions: individual, other members of the household and household. As in the electricity sector, this model needs to be initialized with SHEDS data. However, in SHEDS data, the information on the investment decisions is available at the household level, while the information related to the usage decisions is available at the individual level (respondents). Therefore, we have to use assumptions regarding the links between the two decisions.

In this regard, we have assumed that commuting behavior is the main driver for the investment in mobility. We have considered three categories of commuters depending on the distance driven by car: (i) “long” commuter for distance larger than 27 km; (ii) “short” commuter for distance lower than 27 km and (iii) “no” commuter for those who are not commuting. Based on this categorization, we have set up a decision tree that starts with individual decisions regarding work and leisure activities. We then have determined the individual “optimal” portfolio for work and leisure activities. In addition, we have added the decisions of the other household members to characterize the “optimal” portfolio for the household. We have initialized the model using results from the SHEDS data.

### 3 Activities and results

In 2019, we have extended the timeline for the project by one year compared to the original agenda. This allowed us to re-organize the milestones. In Workstream 1 we have prepared the SHEDS choice experiment and started to analyse it, alongside the data from the 4<sup>th</sup> wave of SHEDS. We have made significant progress in the collection of municipal data in the mobility sector and invested into gathering data on norms at the municipal level. In Workstream 2, the electricity ABM has matured from a prototype model to a full-fledged model with a sufficiently broad set of channels for decision-making, which is now set for calibration. We have also included prices and versatile information-diffusion processes. The mobility ABM has grown a general structure and we have largely finished the initialization phase.



On November 11, 2019, the second workshop with the external expert panel was held where Prof. Dr. Heinz Gutscher, Prof. Dr. Miguel Brendl and Prof. Dr. Paul Burger provided expertise. Empirical results and approaches to measure social norms at the municipal level (Workstream 1) were discussed, as well as modeling approaches regarding information diffusion for Workstream 2.

### 3.1 Workstream 1 “Empirical Analysis”

As part of Workstream 1, the 4<sup>th</sup> wave of SHEDS has been analysed. With four years of data available at this point, confidence in the findings has improved further. The analysis generally confirms the results that were presented in last year’s Annual Report. Households with a high level of energy literacy are on average more likely to have made energy-saving and environmentally friendly investment choices in all three investigated areas of household energy demand compared to households with little energy-related knowledge. There is also evidence for a positive relation between a household’s perception of social norms and such behaviour in the areas of mobility and electricity. Whether a household invests in renewable energy heating and warm water systems on the other hand is not related to social norms.

Looking at usage behaviour, we find both soft measures to be important. Literacy is significantly related to all types of analysed mobility behaviour. The same holds for social norms with the exception of flying behaviour. Here, social norms are positively correlated with the number of flights, whereas literacy has a negative correlation. Contrary to the area of mobility, social norms are more relevant for electricity usage behaviour than literacy. Although energy literacy is correlated with a lower and less frequent use of electric appliances, social norms are significantly related to electricity usage and energy-saving handling of electric devices. Survey respondents, who perceive peer pressure, especially from friends, to behave environmentally friendly, report smaller electricity bills and lower electricity usage than respondents with no perception of such social norms. We find energy literacy to have a concave correlation with electricity usage.

Following up from last year’s annual report, we have further investigated the relevance of soft measures for price elasticities in the area of electricity. Using electricity price information from SHEDS has not delivered insightful results because of the quality of the data. Although respondents are asked to base stated electricity prices on their electricity bills, the recorded responses indicate that this was a difficult task. Hence, we have used publicly available electricity price data that is published by EICOM. We have matched prices for standard electricity tariffs with respondents in the SHEDS based on zip codes and the household classification key used by EICOM. The subsample, for which we could match the price data, consists of households with a standard electricity tariff and which live in municipalities with a single electricity provider. Using this data, we find a price elasticity of -0.88. This result has been achieved using sociodemographic and household-specific control variables. Over our five different household segments, there is no significant variation of the elasticity.

The price elasticity is affected by soft measures. We find energy literacy to have a significant influence on price elasticities. As depicted in Figure 1, households with a low level of literacy have a price elasticity of -0.87 on average, whereas households with a high level of literacy have an elasticity of -0.94. The more elastic electricity demand of highly literate households indicates that their knowledge better equips them to adapt their behaviour to save electricity compared to households with a low literacy. A similar pattern emerges when household heterogeneity is accounted for. It is observed for middle-aged households in urban and rural areas and to a lesser extent in senior households. An urban and middle-aged household with a high level of literacy for example has a price elasticity that is 14 percent higher on average compared to a similar household with a low energy literacy. Among young households on the other hand, literacy does not significantly affect price elasticities.

Next, we have investigated a potential impact of social norms on price elasticity. Contrary to energy literacy, the results show no significant relation between the two. Households, which perceive injunctive



and descriptive norms regarding environmentally friendly behaviour, do not adapt their behaviour differently than households, which do not perceive these social norms, in reaction to a price change. Even when household types are distinguished, social norms do not affect elasticities in the area of electricity.

Whether these results also apply to households with other electricity tariffs than the standard one cannot be answered with this analysis. However, using the full SHEDS sample we have not found a negative feedback effect of more expensive but “greener” electricity tariffs on the electricity consumption of households. Households with a standard electricity mix have on average no statistically different electricity consumption than households with a more environmentally friendly mix.

Besides the analysis of SHEDS data, we are currently in the process of analysing the survey choice experiment data. 947 respondents have completed the experiment. Each respondent was offered pairs of housing options to choose from in the situation of a home relocation. The choice options differed in the previously described three characteristics affecting housing energy demand (see Section 2.1). To make the choice setting more realistic, we have included price information for each housing option that was obtained from a Swiss space development consultancy. Note that the price tag that we have attached capitalizes the (average) market premia for the characteristics of each specific housing option.

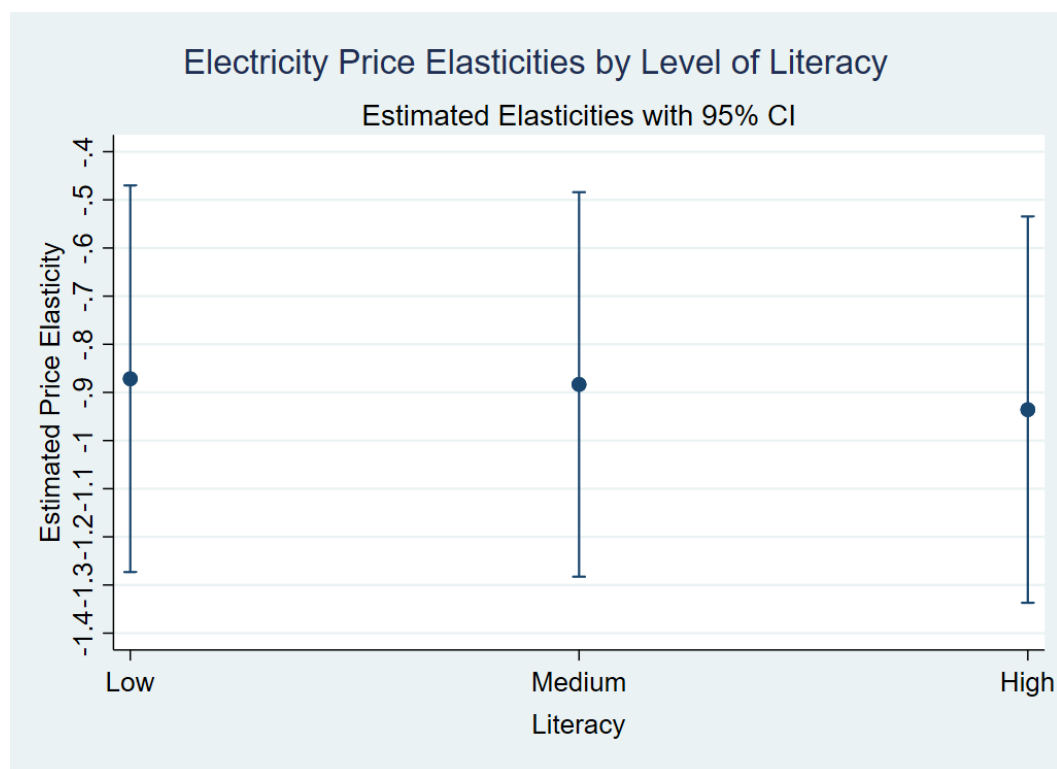


Figure 1: Estimated electricity price elasticities by level of literacy

It therefore does not constitute a fourth attribute.

Survey respondents were randomly assigned to either a control or one of two treatment groups. Treatment groups received messages revealing information pertaining to either economic factors or social norms. The economic incentive treatment group was informed about potential future cost savings when choosing a home with characteristics that support a low energy consumption profile. Respondents receiving the social norms treatment were shown normative messages communicating descriptive and



injunctive norms. These messages communicated the approval of housing choices in favor of low energy consumption profiles in the Swiss society.

As we are interested in behavioral differences across household types in reaction to the treatments, we have segmented households according to our segmentation strategy defined in the Annual Report 2018. Each of our five household types is well represented in the sample with at least 50 respondents within each control and treatment group. We will identify treatment effects separately for each household type and then make a comparison across all of them. In this way, we aim to gain knowledge for a more efficient policy design. If the effects of the two treatments vary significantly over households, the tailoring of these measures might be a more effective intervention compared to one that ignores household heterogeneity.

Preliminary results suggest that the observed behaviour is in line with our hypotheses. Household heterogeneity seems to affect the effectiveness of treatments. There is significant variation in choices over household types and treatments. If the results of the upcoming extensive analysis confirm this first insight, we will be able to provide evidence for the possibility of achieving behavioural changes by tailoring treatments to households.

Regarding our work with municipality data, we have not yet analyzed the data econometrically, as the data set is not yet complete. However, regarding the already available data, the following descriptive statistics (for the three types of municipal variables that we describe in the previous section) can be provided.

|                                    |       | Mean   | Std. Dev. |
|------------------------------------|-------|--------|-----------|
| Population Size                    |       | 3,759  | 12,306    |
| Population density                 |       | 422    | 769       |
| Age distribution (%)               | 0- 19 | 21     | 3         |
|                                    | 20-64 | 61     | 3         |
|                                    | 65+   | 18     | 4         |
| Household number                   |       | 1,644  | 5,862     |
| Household size                     |       | 2      | 0.2       |
| New buildings per 1000 inhabitants |       | 6      | 9         |
| Number of jobs                     |       | 2,268  | 13,005    |
| Average taxable income (CHF)       |       | 72,985 | 32,966    |

Table 1: Descriptive statistics for the municipal data: Socio-demographic and economic variables (N=2240)

|                                                                        |                                 | Mean | Std. Dev. |
|------------------------------------------------------------------------|---------------------------------|------|-----------|
| Percentage of Green and Left vote during national election in 2015 (%) |                                 | 25   | 10        |
| Percentage of vote for environmental ballots per canton (%)            | Ballot 6120: Energy Act (EnA)   | 56.5 | 7.9       |
|                                                                        | Ballot 6080: Nuclear Withdrawal | 44.3 | 8.08      |



|                |                                                                         |       |      |
|----------------|-------------------------------------------------------------------------|-------|------|
|                | Ballot 6050: Sustainable and resource-efficient economy (Green Economy) | 33.76 | 8.14 |
| Green products | LED bulb P (availability)                                               | 0.98  | 0.09 |
|                | LED bulb P (stock)                                                      | 5.34  | 2.12 |
|                | Organic egg (availability)                                              | 0.94  | 0.17 |
|                | Organic bread Autrefois (availability)                                  | 0.57  | 0.36 |

Table 2: Descriptive statistics for the municipal data: Proxies for social norms and information variables (N=2240 municipalities, 623 Migros shops and 498 municipalities with Migros shops)

|                |                    | Mean | Std. Dev. |
|----------------|--------------------|------|-----------|
| Number of cars | Efficiency A       | 72   | 109       |
|                | Efficiency G       | 368  | 257       |
| Travel cards   | Abonnement General | 154  | 365       |
|                | Half fare card     | 800  | 1539      |
|                | Regional card      | 88   | 389       |

Table 3: Descriptive statistics for the municipal data: Mobility behavior (N=2240)

Table 1 shows, for some selected variables, that the standard deviation is very high when compared to the mean. In the analysis, those variables will be normalized with the size of population. For instance, employment rate will replace number of jobs and we will consider household number per 1000 inhabitants. We will use the same approach for selected mobility variables in Table 3. For example, we will normalize the number of cars and travel cards to the population size (per 1000 inhabitants). In addition, we will use the share of each fuel efficiency category in the total number of cars.

In Table 2, we have presented the three most recent environmental ballots that are related to energy issues. In the analysis, we will explore the other energy related ballots as a robustness check. In addition, we will construct an indicator that aggregates all the energy related ballots for the last 10 years. Regarding the green business, we have decided to use the stock information for the LED bulb, as this is available in almost all the Migros shops (98%). We have considered organic eggs, and three types of organic breads (Ciabatta, Autrefois and Twister). Similar to the LED bulb availability, we have chosen not to use information on organic eggs. We will primarily use organic bread “Autrefois” and the other two organic breads will be considered for the robustness check.

### 3.2 Workstream 2 “Agent-based modelling”

As mentioned before, we have made progress relevant for the general scope of the ABM as well as progress for the three individual ABMs (electricity, mobility, heat). Before turning to the three sector-specific ABMs, we first describe the general advances. Of particular importance are the conversations, institutional campaigns, the fine-tuning of the network structures, and the inclusion of prices.



Conversations take place within the different networks, household segments or occur randomly between any two agents. We allow for strong and weak links and an endogenously determined selection of the topic and the direction of influence for any conversation. The strength of the influence is also endogenous as it depends on the openness of the influenced agent towards changes as well as how far away from the “influencer” this agent is.

Institutional campaigns are modelled by a versatile function. We can define the institution (a national agency, such as Energie Schweiz, or local utilities), the campaign period, the channel (injunctive norms, descriptive norms or information), the data source for the campaign, and what the target variable is. Further, we specify, if the campaign implies a one-sided alignment of the target to the source variable (from above or below), or whether it implies a two-sided alignment (towards equation). The effect of the campaign is then determined by the agents’ trust levels or their (stated) previous information processing. Whenever possible, we rely on SHEDS data for this campaign-specification. This works for the trust levels (“Regarding energy and saving energy, how strongly do you trust information provided by [the SFOE/local utility]?”; Likert-scale); it works for information take-up (“From whom have you already taken up recommendation for changing your energy consumption?”, dummy variable); and of course it works for the norm and information characteristics of the agents.

Furthermore, we have fine-tuned the network structures (particularly, the friends and neighbourhood networks) to account for network-specific sorting by “meta-clusters”. Specifically, we allow for neighbourhoods to be (imperfectly) mixed by age (but not by place of residence), and friend networks to be (imperfectly) sorted by cohorts but not (fully) by the place of residence. For our five clusters (with cl1 young urban, cl2 young rural, cl3 middle-aged urban, cl4 middle-aged rural, cl5 senior), this means that for the neighbourhood networks we have had to combine cl1, cl3 and a part of cl5 to the group of urban residents (the rest being non-urban neighbourhoods). And we used a combination of cl1 and cl2 to form a young cohort and a combination of cl2 and cl4 for the middle-aged cohort. (Cl5 is the senior cohort and remains unchanged.)

Another focus of this year’s activity has been the introduction of prices. We have focused on binding budget constraints and demand changes due to price effects (changes in the composition of the expenditure). In agent-based models we are able to model these two effects separately. These price mechanisms are relevant for all three topics of the ABM (electricity, mobility, heat). For the case of electricity, for example, the introduction of prices had implications for both effects. For the analysis of budget constraints, we have redefined the category “rich” (vs. “non-rich”) into the category “poor” (vs. “non-poor”). This allows us to model tight budgets for the poor subgroup of the agents. These are particularly binding for the investment side of the model. For example, poor households have lower replacement rates for small and large electric appliances (following McCollough 2010); or they are less likely to increase their stock of electric appliances. Price effects have been found to be particularly relevant for electricity usage. We have relied on estimates for the long-term price-elasticity of household electricity demand estimated by Boogen et al. (2014). We have further included the (average) electricity price and introduced a linear price trend from one year to the next (based on data from ElCom, available from <https://de.statista.com/statistik/daten/studie/329740/umfrage/haushaltstrompreis-in-der-schweiz/>). For the cases of mobility and heat, the effect of price signals will also be equally considered using the same logic of having effects on tight budgets as well as on changes in demand.

In the electricity ABM, we have furthermore corrected the electricity usage per household for the electricity needed for area and water heating, such that we now only include the residual electricity demand in our model. This level is then divided further into a fixed electricity consumption base and a variable consumption, which depends on how careful and intensive each household uses its appliances. To measure this behavioural component, we have introduced an effort parameter, which is based on household characteristics from SHEDS. It has a stock as well as a dynamic component, comparable to the preferred share of energy-efficient appliances in the investment part. For example, we have used the



question “In the next 12 months, are you planning on reducing your electricity consumption?” to derive the dynamic part. The effort-level can be influenced subsequently by conversations and campaigns and thus affects the variable electric consumption.

In the mobility ABM, we have agreed upon and initialized the general structure of the model regarding the decision tree and how the two decisions can be linked at the three levels of decisions. We have also adopted the categorization of households (which is a refinement of the household segmentation in addition to the five clusters that we use for all models). For example, we have used information regarding the preferred mode of transport for work and leisure activities per commuting behavior (long, short and no commuting distance) as one of the new categories according to which we differentiate households. We have considered the number and the relative share within a cluster for using a car, public transport or soft mobility. As a proxy for the other members of the household, we have used the number of workers in the household. We have used the household stock of cars, Abonnement General and Regional Abonnement at the household level. In addition, we have considered the household stock of electric vehicles as a “minimum” stock because this information in SHEDS is related to only the main car that is used by the respondent.

With regard to the heat ABM, we are set to adapt the general logic of investing into new electric appliances to the investment decision into heating systems. We will need to generalize the binary investment decision that the agents faced in the electricity ABM to suit the multivariate decision between the most important heating technologies (such as gas, heat pump or electric space and water heating).

## **4 Evaluation of results to date**

### **4.1 Workstream 1 “Empirical Analysis”**

As Task 1.1 has almost been finished at the end of last year, the work done this year in Workstream 1 is mostly related to Task 1.2. Regarding work with SHEDS, we have conducted the empirical analysis of Wave 4. Furthermore, we have implemented a discrete choice experiment in SHEDS 2019 and have started to analyze the resulting data.

In 2019, we have completed the first part of the municipal data collection regarding information on socio-demographic and economic characteristics and proxies for social norms and information (Task 1.2). We discussed these proxies during the second workshop with the external experts. In addition, we are finalizing the mobility data collection at the municipal level. Most of the challenges have been in finding appropriate proxies for social norms and information and in matching datasets from different sources.

So far, the work done in Workstream 1 has provided all the planned input for Workstream 2 and has generated important insights into the effect of social norms and information on the different domains of individual energy use as well as on the interaction of prices and these soft instruments. Furthermore, its results clearly indicate that there is sufficient empirical evidence to warrant a deeper analysis of tailored policies in the context of the ABM, as there is substantial heterogeneity in the effects of different measures (soft measures, prices) among the five clusters considered in our analysis.

### **4.2 Workstream 2 “Agent-based modelling”**

In 2019, we have finalized the structure of the electricity ABM, which includes the information and norm diffusion; and we have agreed on the dynamic channels, which affect investment and usage decisions. According to the updated schedule, we promised this milestone by the end of this year. This enables us



to start working on the baseline calibration and validation, such that we see fit to finish Task 2.1 until the end of Q2 2020.

In 2019, we have designed a basic setup of the ABM in the mobility sector. We will mostly have finished the initialization phase by the end of 2019, as promised, even though we acknowledge additional complexity compared to the electricity sector. For example, the “agent” as the object we observe is less clear, as some characteristics are reported for the household as a whole (e.g., car ownership), while others are clearly individual responses (e.g., the mode of transport (MoT) for commuting). So, one of the challenges in setting up the ABM for mobility is to connect investment decisions at the household level to the usage decisions at the individual level. Furthermore, some decision problems are much more complex and interdependent with other decisions (e.g., the MoT decision for work has an effect on the MoT decision for leisure).

For the heating ABM, finally, we have started to work on the initialization of the model and are confident that we will reach the first milestone – initialization until mid-2020.

So far, the analysis in Workstream 2 is progressing well. As was anticipated in the application, the data from SHEDS is not sufficient to generate all information required for the ABM, so that additional assumptions (based on literature and on testing different modelling approaches) are necessary. Substantial progress has been made in this regard, in particular related to information diffusion. After the adjustments to the workplan made during the past year, we expect the work to continue as planned and to generate first usable insights end of 2020/start of 2021.

## 5 Next steps

As discussed at the meeting with the SFOE on June 25, 2019, we have substantially adjusted the workplan to cope with the changes in the research that occurred in 2018. Given that these changes induced substantial delays (as some positions were not filled for some months) and that we extended the empirical part of the project (inclusion of the choice experiment) to gain a better data source, the new workplan extends the project in a cost-neutral way to 2021 (see Figure 2). Note that we also used the update of the workplan to merge the original Tasks 1.2 and 1.3 such that both are now subsumed in Task 1.2.

The planned work in all not yet finished tasks has been adjusted accordingly.



Updated Schedule: Extension to 2021

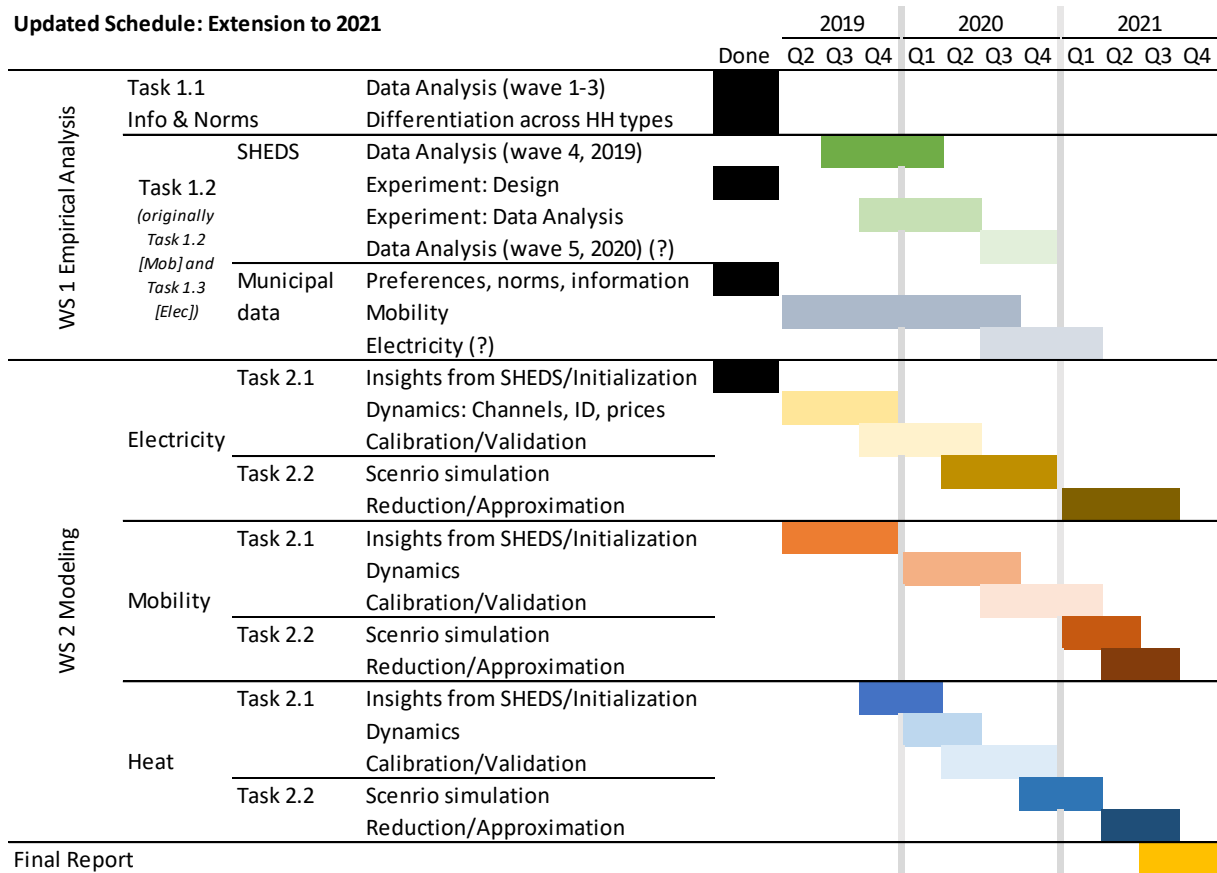


Figure 2: Project timeline (updated for the extension until 2021)

## 5.1 Workstream 1 “Empirical Analysis”

In Workstream 1, we will complete the data analysis of the choice experiment next. This analysis will provide insights about the importance of household heterogeneity for the design of policy instruments in the situation of a decision with a lasting impact on household energy demand. In addition, the findings will also be informational for the agent-based model.

In the last two quarters of 2020, we will conduct the data analysis of the SHEDS wave 2020, which is the final wave to be included in the project. This concludes the work for Task 1.2.

After the completion of the municipality data collection regarding preferences, norms and information, we will finalize collecting data on mobility behavior at the municipal level. We will then write a first draft of the municipal data analysis by January 2020. This analysis will include different model estimations for each dependent variable (travel cards and passenger cars). For comparison purpose with results from SHEDS, we will try to be as close as possible to the methodology and approach adopted in the empirical analysis with the SHEDS data. We expect to present this draft during seminars and conferences in 2020. A final paper on the municipal data regarding mobility will be available by September 2020. The same approach will be adopted for the electricity data at the municipal level. A final draft will be available by January 2021.



## 5.2 Workstream 2 “Agent-based modelling”

The evaluation of the realized progress has already been mentioned in the previous section. With regard to the next steps in Workstream 2, we also have mentioned before that we will finish Task 2.1 for the electricity ABM by mid-2020. We will use the rest of the year for the completion of scenario simulations (first part of Task 2.2).

For the much more complex case of the mobility ABM, we will need until Q3 2020 to implement the required and desired dynamics into the model. We will then use this model to explore some scenarios such that we will finish Task 2.1 for the mobility ABM until Q1 2021. Results from the scenarios will be available by mid-2021.

For the heat ABM, we will have finished Task 2.1 by the end of 2020, where we will profit from our learning curve in both electricity and mobility.

## 6 National and international cooperation

The discrete choice experiment that was implemented in the 2019 wave of SHEDS was designed in cooperation with researchers from the Sustainability Research Group of the University of Basel and from the Institute of Sustainable Development of the Zurich University of Applied Sciences. Furthermore, we obtained price information for the experiment from Fahrländer Partner AG, a space development consultancy from Zurich.



## 7 Publications

Poster      Presented at the 6<sup>th</sup> SCCER CREST Annual Conference: Breaking Boundaries – Linking Sectors? Challenges for the Energy Transition (September 19, 2019 in Sierre)

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