ENERGY SAVING POTENTIAL OF PRIVATE ELECTRICITY CONSUMPTION BY FEEDBACK AND CONSULTING

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Abstract

In the pilot project SM500 of the Vorarlberger Kraftwerke AG the impact of smart metering and the simultaneous implementation of different advisory elements in private households was to be identified. About 500 households were equipped with smart meters and divided into three clusters, each with different advisory elements. In order to allow comparison, two additional clusters (V1 with 140 customers and V2 with 630 customers) were considered. The results show that the use of smart meters in combination with different advisory elements exhibits potential energy savings, whose extent is depending on the type, the quality and the usage intensity of the advisory elements.

The pilot project was academically accompanied by the Forschungsgesellschaft für Energiewirtschaft mbH (Research Association for Energy Economics) in Munich. The main task of the FfE was the development of the methodology, the plausibility check, the processing of data and the reliable quantification of the energy savings.

Motivation

The use of smart meters offers several advantages for private consumers as well as for power supply companies. For example, the consumers´ awareness regarding their energy consumption can be increased by providing related information in a high time resolution. For energy supply companies, smart meters may have a positive effect on power distribution, tariff arrangement, the company's strategic orientation and customer loyalty. According to the EU directive 2009/72/EC, at least 80 % of the households have to be equipped with smart meters until 2020, provided that the introduction of smart meters is evaluated positively [1]. Within the scope of this project, the effect of chosen advisory elements can be investigated systematically.

In Austria, the ordinance of smart metering was adopted on 24.04.2012 [2]. Austria will implement this ordinance in several stages. By the end of 2015 10 % of all households should be provided with smart meters by the power supply companies. By the end of 2017 70 % should be provided and by 2019 the minimum should be 95 %.

Approach and methodology

The major objective of the project is to determine the impact of the different advisory elements on energy consumption of private households in Vorarlberg. Therefore, a comparison of historical and current energy consumption and a comparison of clusters with and without advisory elements are necessary.

At the beginning of the examination, the historical data has to be checked for plausibility. For this purpose, the consumption in the years 2009 and 2010 is compared to the consumption in 2011. In case of extreme deviations which cannot be explained by behaviour modification nor by the use of new technologies, the customer is excluded from further analyzes. If extreme consumption deviations are limited to only one of the years, this year is excluded solely. Customers with an electric heating are excluded from the analyses as well, as in their case weather conditions interfere with the effect of saving.

The validation of available customer's information on electrical hot water generation is based on a load and regression-analysis (**figure 1**). Thereby, the relation between average consumption of every customer during the high-tariff (ht) period and the low-tariff (lt) period in the summer months is formulated. The higher the lt-consumption in comparison to the ht-consumption is during the summer, the higher the plausibility of hot water generation by electricity is. The electrical hot water generation normally starts at night because of the two tariff system used by the customers - with a differentiation of high- and low tariff. The water heating takes place during the lt-period, in order to use a more favorable price per kilowatt-hour. All customers, who are below the defined limit curve, have an electrical water heating. In addition, the daily load curves of these customers are analyzed in detail. Customers with a nightly peak are allocated to the ones with an electrical water heating.

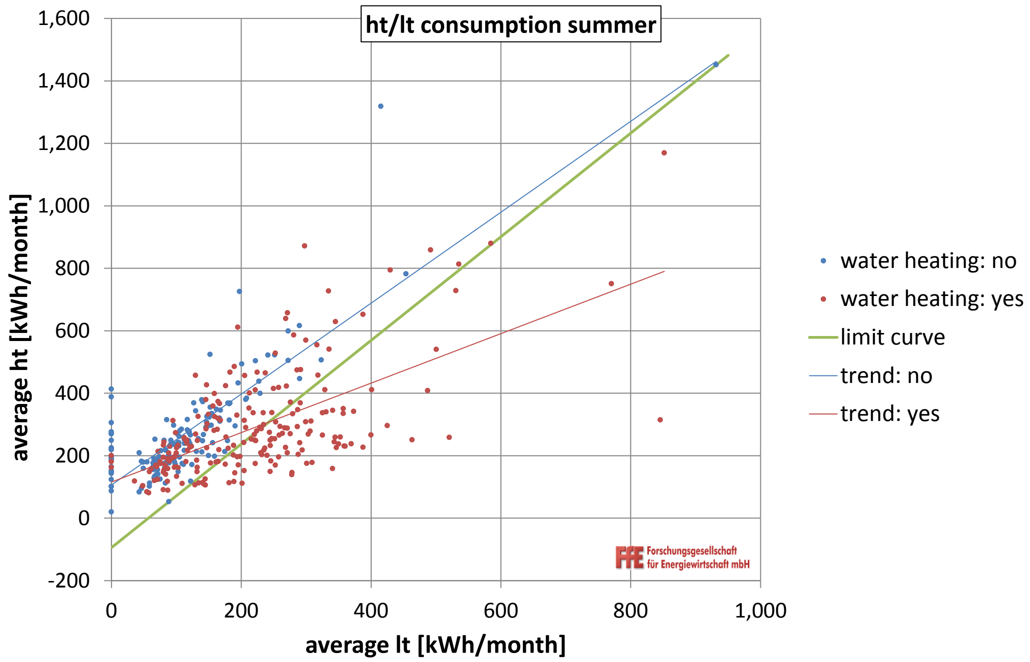

Figure 1: *Relation between ht- and lt-consumption (summer) of every customer in the S-groups, limit curve for electrical water heating*

For the analysis of energy consumption a maximum sample size is chosen to gain reliable results. Then, the consumption figures of the different customers are standardized, because the groups include customers with different consumption-levels. If there was no standardizing, the energy savings of larger consumers would dominate the smaller ones. This proceeding is explained in the following example. **Figure 2** shows two customers with significantly different consumption.

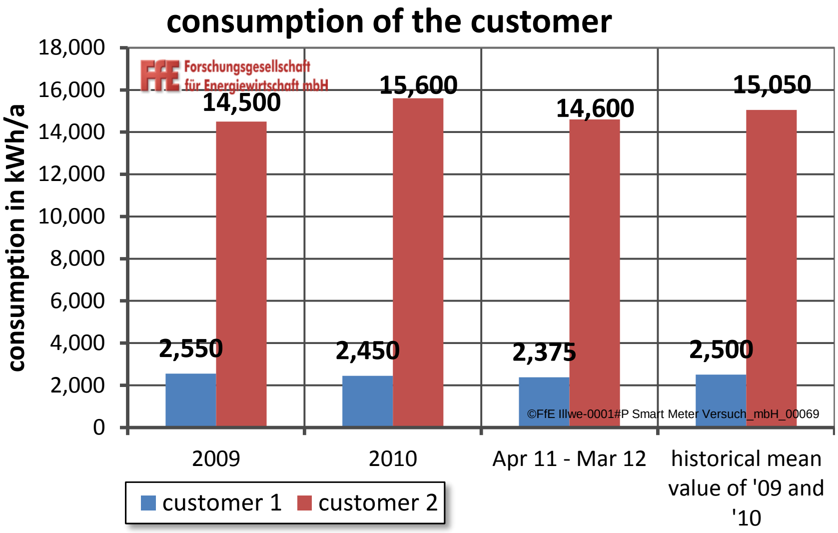

Figure 2: *Comparison of the consumption during the period of 12 month*

Figure 3 shows the absolute and standardized savings of each customer. If the absolute savings are considered only, the influence of the larger consumer is stronger.

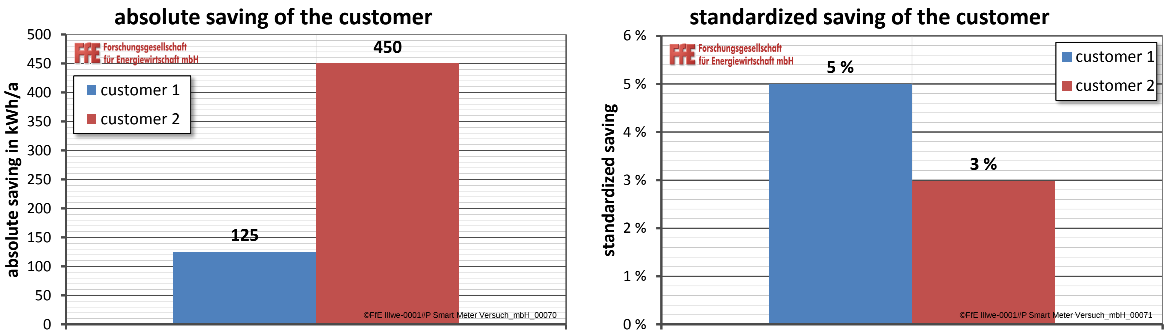

Figure 3: *Absolute and standardized savings of both customers*

Figure 4 shows the absolute and standardized savings of the group. If the standardized savings are chosen, both customers have the same influence on group savings, although individual savings are totally different.

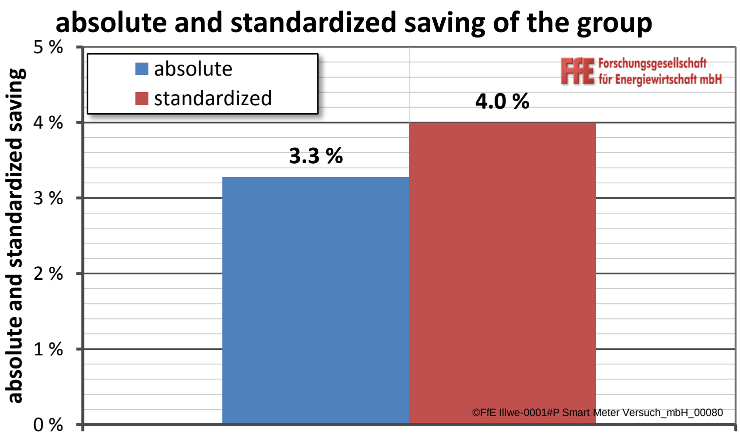

Figure 4: *Absolute and standardized savings of the group*

Simultaneously to the standardized analysis, an analysis of absolute savings is prepared. The evaluation of the consumption data of the 12 months provides reliable results.

Advisory elements

The main advisory element is a **smart meter** from the Yello Strom GmbH. The consumption data is captured once a second. In this study, the analyses of the consumption and the load curves are based on summarized values in a range of 15 minutes, which were transmitted to the server of the Illwerke VKW.

E'klar-Meter is an additional software tool for online visualization of energy consumption at the computer at home. The values are updated every second.

When using the smart meter there is the possibility to utilize the **e'klar-Stromtagebuch** ("e'klar-consumption-diary") via internet, which enables visualization of historical consumption data (minimum data rates; one value every 15 minutes) as a graph or a table. The customer can choose the period, for example a day, a week or a month. In addition to energy consumption, the customer has an overview over the costs.

Another advisory element is the **monthly invoice** of the consumption of the month before.

A more detailed feedback tool is an additional monthly information package composed of savings instructions and a consumption report. This **monthly energy report** presents the consumption data in daily or monthly values. Furthermore, the basic consumption of every day is shown and the days are separated into workdays and weekends. In addition, a comparison of historical consumption of the last few months is made in graphical and tabular form.

There is a personal on-site **energy consulting** carried out by the employees of the Illwerke VKW. They are analyzing the consumption behavior of the customer by using a load-curve tool, which has been developed within the project. Finally, the customer is advised regarding energy efficiency and energy savings.

Additional to the advisory elements, the consumption behavior of the participants of the **„Stromsparmeisterschaft"** (Energy-Saving-Competition) between Nütziders and Zwischenwasser was examined. This study has been started before the smart meter project. Participants of the competition had to fill in their consumption data on an internet platform and received a present as a reward. For collecting the data of those customers, an employee of the Illwerke VKW evaluated the energy meters of these customers each month.

Definition of the customers

In autumn 2009 the pilot project was presented to the public. Interested clients could apply for participation of the project at the Illwerke VKW. Nearly 1.000 private households were interested, but only 500 could be chosen and provided with smart meters. 10 per cent of the participants were employees of the Illwerke VKW. Two of the requirements for participation at the project were, for example, available historical consumption data of the last two years and the technical facilities to install a smart meter device.

Definition of the cluster

Five clusters were defined for the determination of the consumption reduction caused by smart meters and the effect of different advisory measures. The clusters S1, S2 and S3 consist of households with smart meters with different advisory elements. A monthly invoice was delivered to all households of those smart meter clusters. The customers of cluster S2 received an additional personalized energy report. Only customers of cluster S3 received energy consulting. In order to enable comparison, two additional clusters (V1, V2) without smart meters were defined. The customers of V1 participated in a competition and were monitoring electricity savings and received a monthly invoice. A sixth of V1 customers were provided by energy consulting as well. The customers, who were clustered in V2, were not aware of their function as a control group. They got their normal annual invoice. **Table 1** shows the number of customers in the cluster, as well as the advisory elements.

Table 1: *Smart meter- and comparison-cluster – the different advisory elements*

<table>
<tr><th>Cluster</th><th>number of customers</th><th>feedback- & advisory elements</th><th>consumption recording</th><th>comments</th></tr>
<tr><td>S1</td><td>211</td><td>· indication per second
· internet platform
· monthly invoice</td><td>every 15 minutes</td><td rowspan="3">A part of the smart-meter-users were VKW-employees.</td></tr>
<tr><td>S2</td><td>140</td><td>· similar to S1
+ monthly personal energy report</td><td>every 15 minutes</td></tr>
<tr><td>S3</td><td>120</td><td>· similar to S2
+ energy consulting</td><td>every 15 minutes</td></tr>
<tr><td>V1</td><td>142</td><td>· monthly invoice
· monthly local metering</td><td>monthly</td><td>Energy-saving-competition</td></tr>
<tr><td>V2</td><td>633</td><td></td><td>annually</td><td>Selection consistent with S1-S3 & V1</td></tr>
</table>

Period of investigation

The period of investigation of the pilot project is about 15 months and started in March 2011 and came to an end in May 2012. The consumption data was collected in a range of 15 minutes for the clusters S1, S2 and S3. The data of the clusters V1 and V2 was collected monthly respectively annually. In order to have a high number of installed smart meters and a reliable real (no trend) data volume of V2 customers, the analysis included the period from April 2011 to March 2012. These are exactly 12 month.

Results

The time-based development of the consumption in the different clusters is shown in **figure 5**. There is a significantly stronger seasonal influence than an influence of the advisory elements. Therefore, it is necessary to evaluate the consumption data over a period of 12 month to receive reliable results.

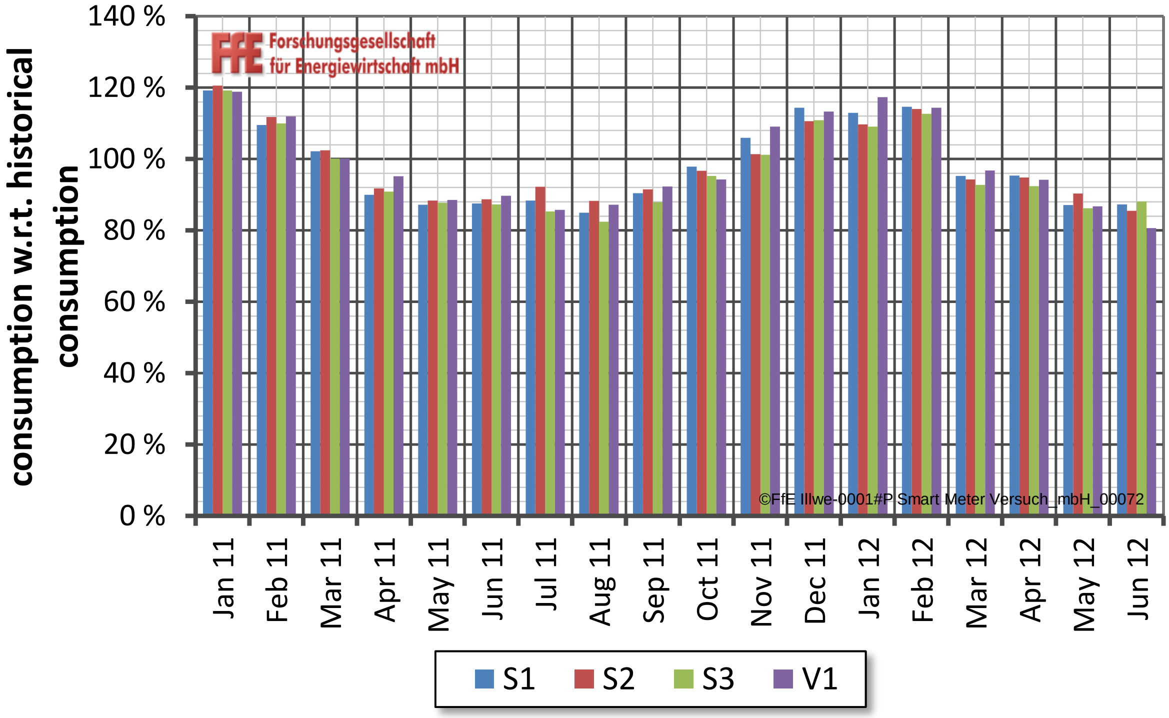

Figure 5: *Monthly consumption related to the historical consumption*

Figure 6 shows the historical consumption and the consumption of the current investigation period from April 2011 to March 2012. Comparing the period from April to March with the historical basis (black line), it is obvious, that there are energy savings within all clusters. However, the savings in the comparison group V2 are the smallest.

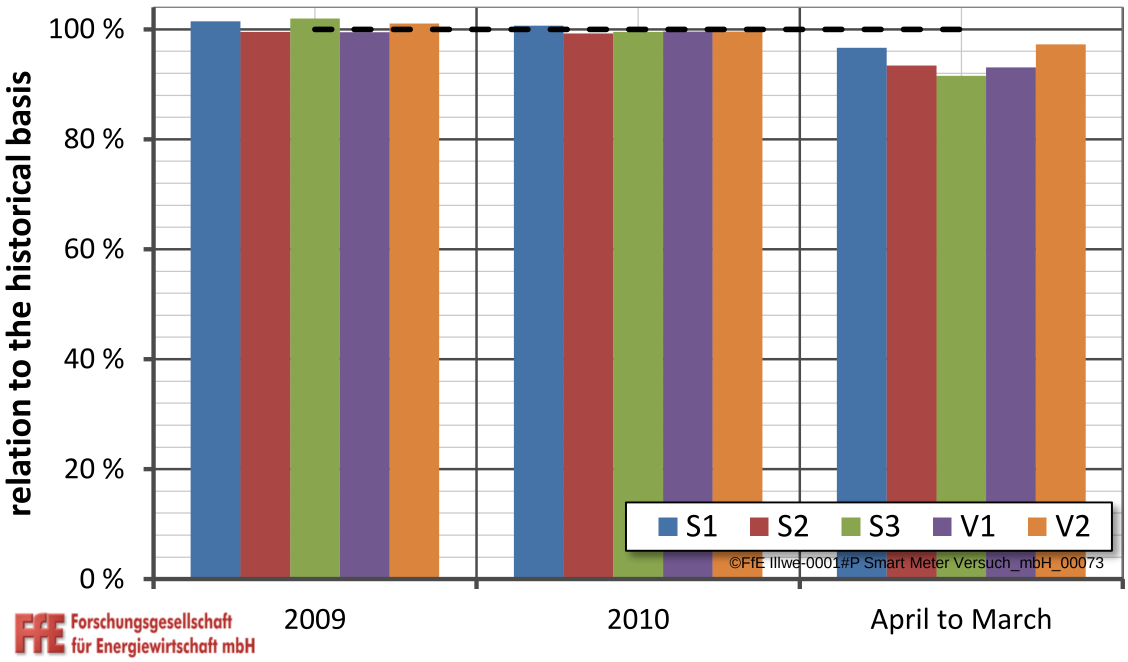

Figure 6: *Consumption during the investigation period and the years 2009 and 2010 related to the historical reference value*

In conclusion, the higher the quality and the intensity of the advisory elements are, the higher the energy savings are (**table 2**).

Table 2: *Energy savings in each cluster*

Cluster	feedback- & advisory elements	consumption recording	comments	Savings in comparison to 2009 & 2010	additional savings in comparison to cluster V2
S1	· indication per second · internet platform · monthly invoice	every 15 minutes	A part of the smart-meter-users were VKW-employees.	**3.38 %**	**0.63 %**
S2	· similar to S1 + monthly personal energy report	every 15 minutes		**6.62 %**	**3.87 %**
S3	· similar to S2 + energy consulting	every 15 minutes		**8.43 %**	**5.68 %**
V1	· monthly invoice · monthly local metering	monthly	Energy-saving-competition	**6.90 %**	**4.15 %**
V2		annually	Selection consistent with S1-S3 & V1	**2.75 %**	

Cluster V2 shows general savings without the use of smart metering or advisory elements in comparison to 2009 and 2010. For that reason, the energy savings of the clusters S1, S2, S3 and V1, which refer to advisory measures, correlate with additional savings compared to the savings of cluster V2 (green column). Considering all smart meter clusters, the lowest savings (0.6 %) are achieved in cluster S1. The sending of a personal monthly energy report improves the savings to 3.9 % (cluster S2). Better results (4.2 %) are achieved by cluster V1, which is without smart metering but part of the energy competition. In cluster V1 the personal contact to the VKW meter-reader could have had a similar effect as the monthly energy report in cluster S2. This fact should be considered in further smart meter projects. The highest savings (5.7 %) are achieved via personal energy consulting in cluster S3.

Even if the employees of Illwerke VKW are implicated, the results are basically the same. The savings of cluster S1 improve a little to 1.0 %, the additional savings of S2 decrease a little to 3.1 % and the cluster S3 is nearly stable with 5.6 %.

Validity of the results

The following described methodology is used in order to determine the significance of the observed consumption change in every cluster. In simple terms, this method defines the probability of the average observed consumption change μ in one group (μ_{group}) assuming that usually, only such consumption changes occur which are comparable to the average consumption change μ_{V2} in cluster V2.

For a group with N electricity consumers a random value for each consumer is chosen from a K-element pool of the comparison group V2. It is possible that the same value is chosen again (binominal distribution). For the pool the consumption change of the consumers in cluster V2 is measured, that is why a pool of 605 possible values exists. In other words, for a smart meter group with 150 participants (N=150) a consumption change is chosen randomly for each participant (150 times) from a pool of 605 possible values (K=605). The mean value μ^* is formed out of the N selected values. This selection process is repeated 1.000.000 times.

Finally, the measured mean value μ_{group} is compared to the calculated mean values μ^* on the basis of the pool of the comparison group V2. Therefore, it is counted how many of the 1.000.000 calculated μ^* have a greater absolute deviation from μ_{V2} than μ_{group} from μ_{V2}. This number is divided by the number of selections. The following result gives an idea of the significance of the measured consumption change.

Figure 7 shows a histogram of 1.000.000 selections of a group with 191 participants. The measured deviation is set to -3.7 %. Each selection with a mean deviation equal or less than -3.7 % is pigmented blue. Each selection with a mean deviation greater than -3.7 % is pigmented red. The relation of the number of red colored results to the number of all selections is equivalent to the significance of the deviation. For this example it is about 91.7 %.

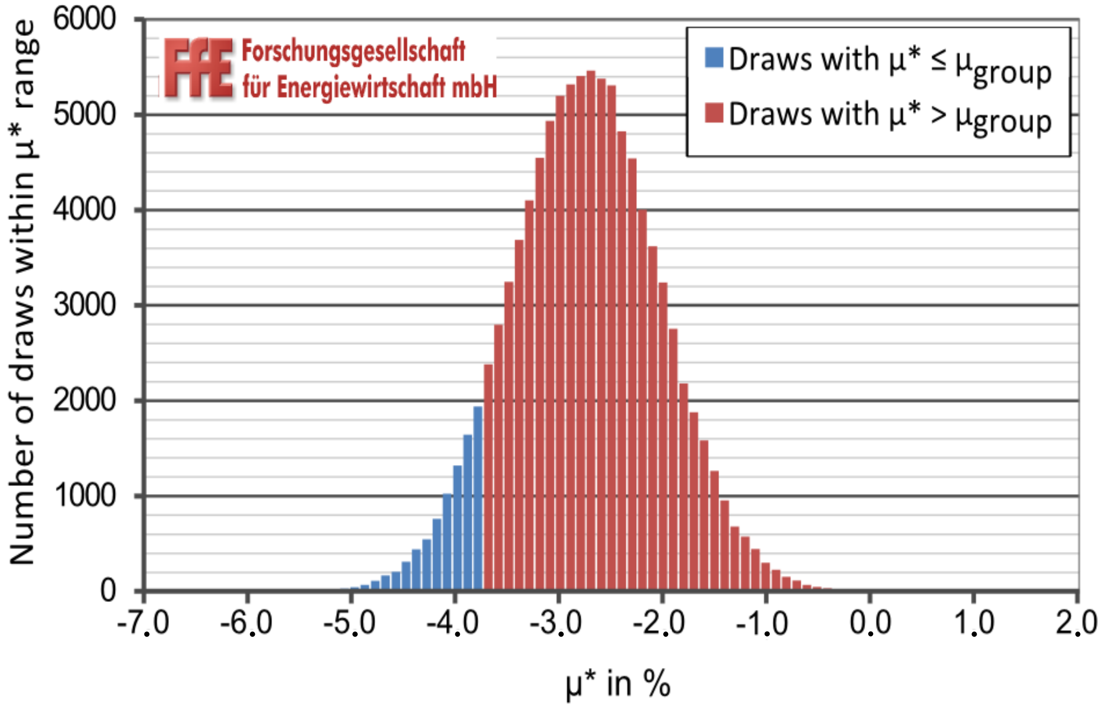

Figure 7: *Distribution of the calculated mean value μ**

Table 3 shows the probability of a randomly appearing measured decrease of power consumption.

Table 3: *Probability of the outcome*

Cluster	Savings	Probability, that a deviation of the power consumption occurs, which is greater than the observed deviation in V2
S1	3.4 %	9.281 %
S2	6.6 %	0.029 %
S3	8.4 %	0.000 %
V1	6.9 %	0.001 %

The probability that the consumption reduction in the measured or in a greater dimension is randomly, is at 0.029 % for S2, less than 0.000 % for S3 and at 0.001 % for V1. Therefore, the measured consumption reduction occurs particularly due to the use of the feedback- and advisory elements. Solely the measured deviation in cluster S1 occurs randomly and therefore the result cannot be explained by the usage of feedback and consulting.

Extrapolation to Vorarlberg

The extrapolation of the saving potentials by the use of feedback- and advisory elements in Vorarlberg is based on two scenarios. In both scenarios every household is provided with smart meter. In addition, advisory elements like e'klar-Meter and e'klar Stromtagebuch are used. Furthermore, every household gets a monthly invoice and an energy report. Those advisory elements are highly automatable and have the highest potential to be used in reality in case a smart meter is installed. The differences between the two scenarios are the following:

1. In a “maximum scenario” every household achieves similar high-percentag savings like the customers in cluster S2,
2. In a “moderate scenario” the customers are separated in sub-groups similar to the Capgemini-Study [3]. This study is separated into 20 % of enthusiasts, 40 % of followers and 40 % of uninterested persons. It is assumed that the enthusiasts achieve equal savings to cluster S2 (3.9 percent). The uninterested persons achieve no savings and the followers are in-between at 1.4 percent.

The power consumption for electric heating is subtracted from the private total power consumption. For the residual power consumption the savings are calculated for both scenarios. The absolute savings are between 8 GWh/a in the moderate scenario and 24 GWh/a in the maximum scenario. The cost savings for a household with an average power consumption and a saving success like cluster S2 are about 30 € per year. According to Illwerke vkw, the costs for the customers are at 8 to 23 € per year. The savings for Illwerke vkw are just at 3 to 8 € per year (based on the assumption of a wholesale price of 50 €/MWh) because of the almost constant costs of the grid.

Comparison of the results with other studies

In other smart meter projects and investigations about the influence of feedback- and advisory elements, the savings are quite similar to those in cluster S1 and S2. In **table 4** the savings of the other projects are shown. No smart metering was used in the Velix project.

Table 4: *Saving potentials in other studies*

	Velix	Intelliekon	E-Motivation	IZES Praxistest
Reduction of the power consumption related to the comparison group	2.7 %	3.7 %	3 % to 4.5 % The comparison group also used smart meters	1.7 %

Source: Velix [4, 5]; Intelliekon [6, 7]; E-Motivation [8]: IZES-Praxistest [9]

Conclusion

Based on the academic supervision and the examination of the savings of the pilot project, there is the following key message:

The use of smart meters in combination with feedback- and advisory elements causes a consumption reduction. The amount of the reduction is dependent on the quantity, the quality and the frequency of usage of these advisory elements. These parameters influence the amount of savings essentially. Savings due to smart metering in cooperation with a web portal and a monthly invoice are just at about 1 %. Savings according to the PwC-Study [10] are at about 3.5 % and thus clearly higher. The continuously external impulse (for example the meter-readers of the power competition or the personal energy report in cluster S2 and S3) has a significant influence on the amount of savings. An additional energy consulting (cluster S3) can clearly improve the amount of savings once again. So far, one year has been investigated. That is why sustainability of the measured savings cannot be guaranteed. It has to be examined how savings in the different clusters will develop regarding a longer investigation period.

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