This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 696084

DELIVERABLE

Project Acronym: REScoop Plus

Grant Agreement number: 696084

Project Title: REScoop Plus

D2.3 – Data Analysis Report

Revision: V1

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REVISION HISTORY AND STATEMENT OF ORIGINALITY

Revision History

Revision	Date	Author	Organization	Description
V0	04-04-17		TUC	Final version
V1	04-04-2017	MN	LVLUP	Peer Review

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

EXECUTIVE SUMMARY

This deliverable presents the statistical analysis methodology, and its results on the datasets that the collaborating REScoops provided. The data submitted and analyzed came in the pre-agreed format, described in the previous WP2 deliverables. The statistical analysis was on the current state of REScoops' data, i.e., before the application of any "best energy efficiency practices" yet to be identified by the project and proposed to the REScoops.

The data and delivery processes, described in this and previous deliverables, illustrated the challenges facing REScoops when performing such tasks: data collection is challenging due to lack of metering equipment, different data storage protocols, privacy legislation, and the heterogeneous information sources involved.

Once data was collected, we employed the methodology described in D2.2, to statistically analyze energy consumption related data from 6 REScoops, and assess the impact of the various EE interventions that these REScoops have already implemented. This deliverable describes in the appropriate detail the exact statistical methods used for the analysis, and provides an extensive report on the analysis results. The results were quite encouraging, illustrating to some extent that the formation of REScoops and specific practices already adopted by them lead to increased energy efficiency and environmental benefits. Specifically:

- Joining a REScoop leads to more than 20% reductions in energy demand.
- Installing energy production equipment reduces REScoop members' electricity demand by more than 45%.
- Subscribing to consumption monitoring and savings suggestions software platforms results to approximately 35% consumption reduction.
- Performing successful EE interventions of various types, such as technical support, special tariffs, energy generation schemes, installing smart meters, leads to substantial reductions as measured in various consumption indices: Specifically, technical support leads to 20% reductions in kWh/HDD, special tariffs show 22% reductions in kWh/m^2, energy generation schemes show 24% in kWh/DD, and smart meter installation shows 29% reduction in kWh/DD.

In general, the statistical analysis shows that REScoop members significantly contribute to energy conservation and to the reduction of harmful gases emissions (a projection given analysis results estimates these savings as approximately 1,500 tons of CO_2 per month).

ACRONYMS – ABBREVIATIONS

All acronyms and abbreviations used in the report should be listed in alphabetical order in the list below (other than symbols for units of measurement) in the following way:

ANOVA	Analysis of Variance
DSO	Distribution System Operator
EC	European Commission
EE	Energy Efficiency
HDD	Heating Degree Days
KDE	Kernel Density Estimation
NDA	non-disclosure agreement
REScoop	Renewable Energy Sources Cooperative
TSO	Transmission System Operator
TUC	Technical University of Crete
WP	Work Package

1. Introduction

The RESCOOP PLUS project aims to promote the energy saving activities among the European REScoops that in recent years have been multiplied in numbers [1]. Energy consumers' active participation in conservation activities, and in self-production processes as well, seem to be the only natural way to achieve European Commission's (EC's) targets for near-zero carbon footprint, 100% renewable energy consumption, and energy democracy [2].

The goal of Work package 2 (WP2) is to statistically assess the impacts of various energy efficiency (EE) interventions on consumption reduction and highlight the most effective ones in a recommendations toolkit, which the newly formed cooperatives can, later on, take advantage of it, to achieve even better performance in meeting the consumption reduction targets. The steps for achieving the goals of WP2 (Figure 1) are the following:

1. Share *information* and *knowledge* regarding *data storage and handling*, and also *EE and consumption reduction behavior,* among REScoops.
2. Identify and record *existing datasets* and *their format.*
3. Conclude on *a common data format* for all cooperatives. This includes the definition of a data structure, as well as the fields that will contain the various measurements.
4. Gather available datasets of the supplying REScoops
5. *Initial statistical analysis.* Analyze the historical data before the REScoop Plus project was initiated. This step will give us a first glimpse of what happens in general to the consumption of the cooperative members, and of how existing EE interventions are being applied. *The results will help identify:*
    a. Whether reduction is indeed taking place in REScoops.
    b. Potential key factors for consumption reduction.
        i. These factors can then be taken into consideration by WP3 and WP4 to help identify good behavioral practices and EE interventions.
6. Application of specific EE interventions to certain members and member groups.
    a. These interventions will have to be pinpointed by WP3, after also observation of the initial statistical analysis results
7. Gather available datasets after the application of the EE interventions.
8. *Final statistical analysis.* Analyze the impact of each EE measure to the consumption of the end-users.
    a. This will help characterize the efficiency of each proposed EE intervention and will enrich the recommendations toolkit offered to REScoops.

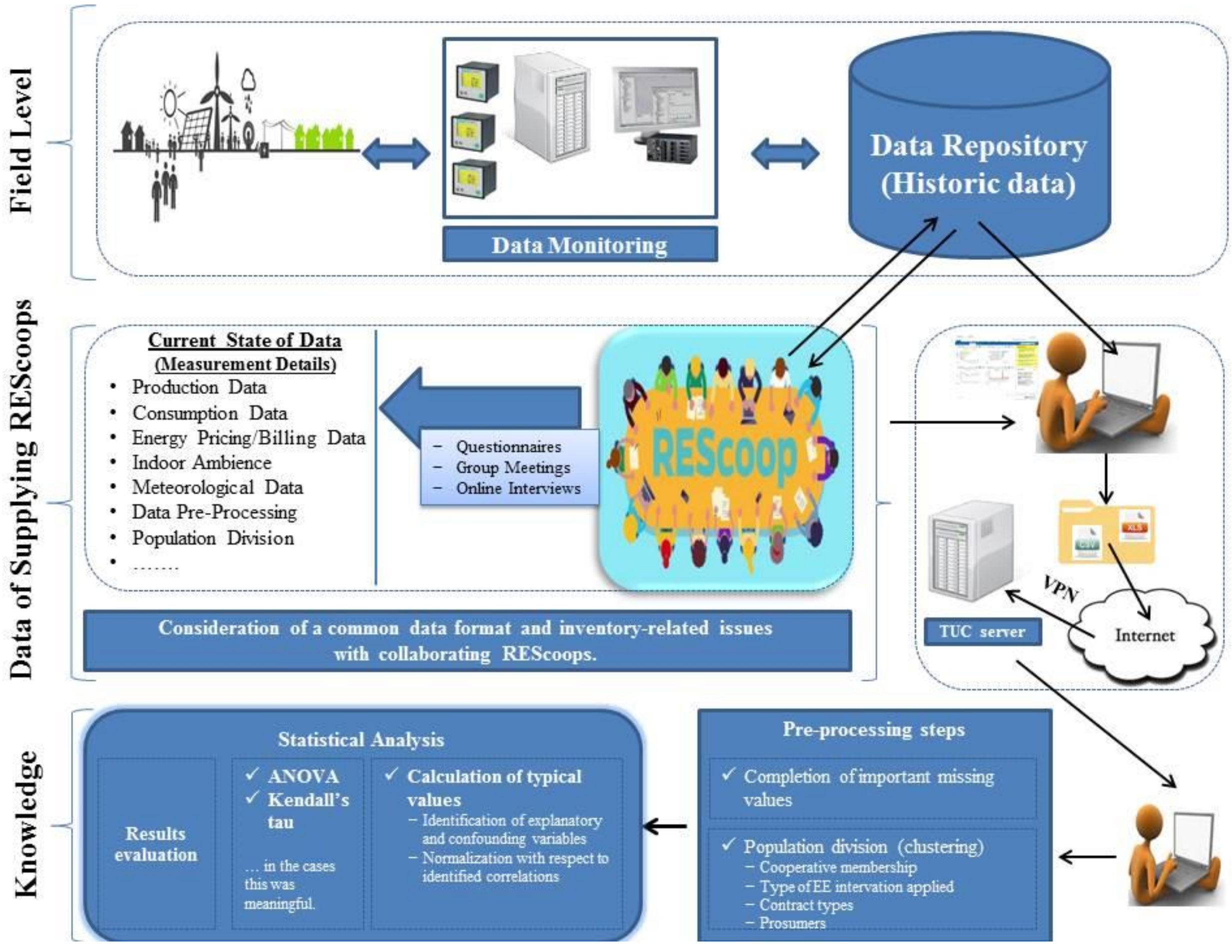


Figure 1: Overview of REScoop Plus research methodology

In deliverable D2.1 - Zero Point Report on Data of Supplying REScoops [3], we have researched the state of data that REScoops collected at the beginning of the project. The research process included questionnaires, interviews, and physical meetings with the data experts, and highlighted the importance of a common data format to be adopted by the participating REScoops. The stored data are then handed over to the statistical analysis team, which will assess the performance of the various EE interventions. The D2.1 covered steps 1 and 2 of the list above.

In the deliverable D2.2 - Methodology for analysis [4], we defined a particular data format that can make the statistical analysis process more convenient, and guarantee to the extent possible that the results are meaningful and realistic. We also outlined the tools that constitute the statistical analysis, such as statistical hypothesis testing, regression techniques, and population division in groups; D2.2 covered the third step of the list above.

In this deliverable we report the progress of the data acquisition process, note the barriers and issues regarding data submission, and present the results of the initial statistical analysis (steps 4. and 5. from the list above). We describe the components that where utilized, both for data transmission, such as bilateral legal agreements and secure storage systems, and for the statistical analysis as well, e.g. group divisions, typical values calculation, statistical hypothesis testing, and key performance indicators definitions.

As the results indicate, the majority of EE interventions already applied by the REScoops, are quite effective in inducing more efficient energy consumption behavior, achieving more than 20% reductions. Importantly, for the cases that data was available, results indicate that becoming a REScoop member leads to “greener” customer behavior.

This document is further structured as follows:

Section 2 discusses the legal agreements made between TUC and REScoop representatives and describes the secure data submission and storage system.

Section 3 reports on the data collection and preprocessing steps that where required to draw safe and realistic conclusions from the statistical analysis.

Section 4 describes the statistical analysis process and explains how results can be interpreted.

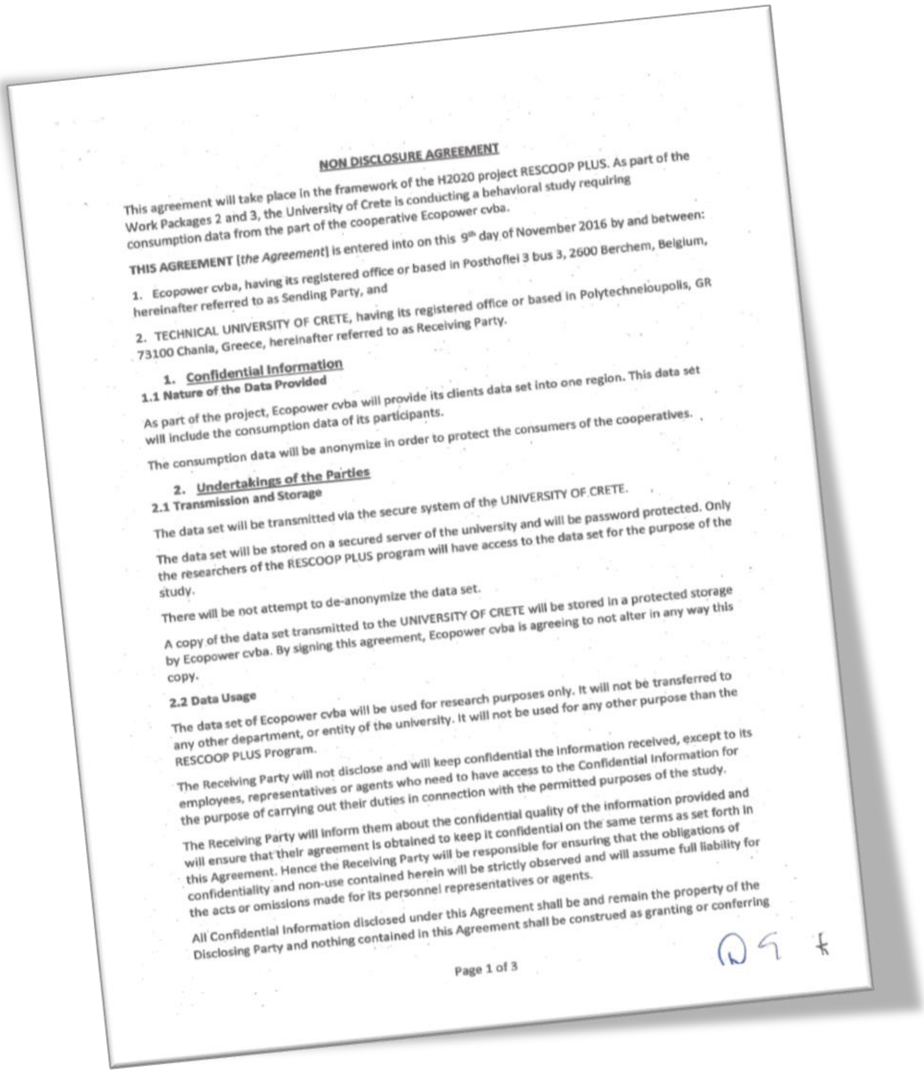
Section 5 presents the figures and numerical results of the statistical analysis for each of the REScoops.

Section 6 summarizes the results from the initial statistical analysis.

Section 7 outlines the future work of WP2.

2. Privacy Protection Non-Disclosure Agreements

During the data submission process, there have been reported serious privacy issues from the REScoops regarding the submission of the datasets. More specifically, the requested data included consumption measurements of individuals, as well as demographics, which are personal information and are subject to strict privacy regulations. To overcome this issue, the TUC team signed non-disclosure agreements (NDAs) with each individual REScoop, committing to not publish any private critical information that could be used to track down individual households and assess their monthly consumption.



NON DISCLOSURE AGREEMENT

This agreement will take place in the framework of the H2020 project RESCOOP PLUS. As part of the Work Packages 2 and 3, the University of Crete is conducting a behavioral study requiring consumption data from the part of the cooperative Ecopower cvba.

THIS AGREEMENT [*the Agreement*] is entered into on this 9th day of November 2016 by and between:

1. Ecopower cvba, having its registered office or based in Posthoflei 3 bus 3, 2600 Berchem, Belgium, hereinafter referred to as Sending Party, and

2. TECHNICAL UNIVERSITY OF CRETE, having its registered office or based in Polytechneioupolis, GR 73100 Chania, Greece, hereinafter referred to as Receiving Party.

1. Confidential Information

1.1 Nature of the Data Provided

As part of the project, Ecopower cvba will provide its clients data set into one region. This data set will include the consumption data of its participants.

The consumption data will be anonymize in order to protect the consumers of the cooperatives.

2. Undertakings of the Parties

2.1 Transmission and Storage

The data set will be transmitted via the secure system of the UNIVERSITY OF CRETE.

The data set will be stored on a secured server of the university and will be password protected. Only the researchers of the RESCOOP PLUS program will have access to the data set for the purpose of the study.

There will be not attempt to de-anonymize the data set.

A copy of the data set transmitted to the UNIVERSITY OF CRETE will be stored in a protected storage by Ecopower cvba. By signing this agreement, Ecopower cvba is agreeing to not alter in any way this copy.

2.2 Data Usage

The data set of Ecopower cvba will be used for research purposes only. It will not be transferred to any other department, or entity of the university. It will not be used for any other purpose than the RESCOOP PLUS Program.

The Receiving Party will not disclose and will keep confidential the information received, except to its employees, representatives or agents who need to have access to the Confidential Information for the purpose of carrying out their duties in connection with the permitted purposes of the study.

The Receiving Party will inform them about the confidential quality of the information provided and will ensure that their agreement is obtained to keep it confidential on the same terms as set forth in this Agreement. Hence the Receiving Party will be responsible for ensuring that the obligations of confidentiality and non-use contained herein will be strictly observed and will assume full liability for the acts or omissions made for its personnel representatives or agents.

All Confidential Information disclosed under this Agreement shall be and remain the property of the Disclosing Party and nothing contained in this Agreement shall be construed as granting or conferring

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Figure 2: Non-Disclosure Agreement paper

In particular, regarding the data usage, the text of the NDA (Figure 2) explicitly states that:

"*TUC will not disclose and will keep confidential the information received, except to its employees, representatives or agents who need to have access to the data set for the purpose of carrying out their duties in connection with the permitted purposes specified in clause […]*

The data set disclosed under this Agreement shall be and remain the property of the <RESCOOP X> and nothing contained in this Agreement shall be construed as granting or conferring any rights to the data set on the other Party. Principally, nothing in this Agreement shall be deemed to grant to the

TUC a license expressly or by implication under any patent, copyright or other intellectual property right.

The TUC hereby acknowledges and confirms that all existing and future intellectual property rights related to the Dataset are exclusive titles of <RESCOOP X>. For the sake of clarity based on reciprocity and good faith of the Parties, the Receiving Party will not apply for or obtain any intellectual property protection in respect of the Data Set received. Likewise, any modifications and improvements thereof by the Receiving Party shall be the sole property of <RESCOOP X>. No copies will be made of the data set by the TUC, its personnel or a third party.

The TUC shall promptly return or destroy all copies (in whatever form reproduced or stored), including all notes and derivatives of the Dataset, disclosed under this Agreement, upon the earlier of the completion or termination of the dealings contemplated in this Agreement; or the termination of this Agreement; or at the time <RESCOOP X> may request it to the TUC. "

As far as the publication of the dataset itself is concerned, the NDA-covered this aspect as follows:

"The data set of <RESCOOP X> will not be published by TUC as part of the publication of the study part of the RESCOOP PLUS program.

In the case of the necessity of verification of the data set by a third party, the TUC has the right to request the copy of the data set from <RESCOOP X>. The conditions of <RESCOOP X> providing this copy will be discussed then''.

Thus, to comply the results that TUC and the other RESCOOP PLUS collaborators will publish will include average values, of groups with more than one individual, making this way impossible to link with the actual consumption measurement of any individual REScoop customer. In parallel, these average indices are able to provide adequate intuitions on the effectiveness of each EE intervention that REScoops apply, fulfilling this way both the restrictions regarding privacy, and the RESCOOP PLUS project's obligations regarding the expected outcome and results.

Agreements between TUC and individual collaborators

In addition to the NDA, special affirmations were signed by each individual collaborator of the TUC team that would have access to the data. The affirmations explicitly stated that:

"*I have been informed for the confidentiality of data and undertake to treat the information as confidential, particularly as to the responsibility of the TUC in the case of violation of this obligation on behalf of the staff (Article 2.2., Paragraph 2 and 3 for the use of relevant data contracts)."*

This way it is assured that the privacy of REScoop customers will not be violated by any means.

Secure Transmission and Storage

In the signed NDAs, there were also clauses regarding the secure transmission and storage system that TUC would have to incorporate in the process. More specifically the NDA stated:

"*The data set will be transmitted via the secure system of the TUC.*

The data set will be stored on a secured server of the university and will be password protected. Only the researchers of the RESCOOP PLUS program will have access to the data set for the purpose of the study.

There will be no attempt to de-anonymize the data set.

A copy of the data set transmitted to the TUC will be stored in a protected storage by <RESCOOP X>.<RESCOOP X> will not alter in any way this copy."

To fulfill this part of the NDA, TUC utilized its Virtual Private Network (VPN), which by all means restricts access to anonymous and non-authorized users. Also, the VPN is used by the REScoops to access TUC isolated and secure servers, on which the data is stored.

The isolated storage servers can be accessed only via using specific accounts that were created especially for the REScoops experts.

The process that each REScoop data expert should follow to use the secure submission system and send the dataset is summarized by the following:

Guidelines for Secure Data Submission

To submit your datafiles using TUC's VPN and storage servers, please follow these steps:

1. Set up your network settings to be able to connect via VPN. Step-by-step procedures for various operating systems are available here <link>:
2. Connect to the VPN using your unique ISC account (to be communicated directly to each partner via Skype).
3. Use secure shell software to connect to our storage system (e.g. ssh/scp commands for Unix-like systems, or download SSH secure shell client for MS Windows).

   Server address: <link>

   Username & password: to be communicated directly to each partner via Skype
4. Upload your files in your home folder at the alchimix3 server.
5. Notify us by e-mail (xxx@yyyy.xyz) when the upload is finished.

Please contact TUC representative directly via Skype for the communication of your user account credentials.

3. Data Collection and Pre-Processing

As stated in the project description [1], the main task of WP2 in task 2.3 was to collect the data and perform a comprehensive statistical analysis to help highlight the best practices that REScoops have already implemented. In this section, we describe the difficulties that REScoops had in gathering and submitting the datasets, and the additional preprocessing that had to be performed by TUC's side.

As can be seen in D2.1 [3], the REScoops that participated in the data submission process were 7 in number, i.e. EBO from Denmark, ECOPOWER from Belgium, ENERCOOP from France, SOMENERGIA from Spain, SEV from Italy, ENOSTRA (AVANZI) from Italy as well, and COOPERNICO from Portugal. We now describe the reported difficulties from the REScoops.

Note on challenges confronted by REScoops

Regarding the young cooperatives, ENOSTRA and COOPERNICO, since they are quite newly formed, their customer-member lists are short. We must note that, in general, newly formed REScoops have many vital tasks regarding the cooperative's constitution, the urge to overcome legal barriers where these exist, and the expansion to more customers and members might come second in this early state. In addition, automatized systems for data collection and analysis are not set up, thus the process is quite a time-consuming since it must be performed manually, often having to combine different data sources, e.g. analyze the data of the Distribution System Operator (DSO), and extract consumption information from the billing system. Nevertheless, both cooperatives contributed with their available measurements in WP2.

Now, regarding the older and more incumbent cooperatives, important challenges exist there too. First of all, the individual data collection and storage systems do not share a common data format, and data restructuring is imperative in most cases. Also, the granularity of the stored measurements varies, from 15-minute intervals to yearly values. In D2.2 [4] we stressed that monthly values would be best for the project's purposes---provided also the strict experimentation time horizon due to the restricted time horizon of REScoop Plus---however, in cases where monthly data is not available, the analysis is going to be performed in 6-monthly, and yearly measurements as well.

Another difficulty that REScoops faced, was the retrieval of meteorological data. Being strictly energy companies, they rarely store weather measurements, such as air temperature, precipitation and degree days, thus, third-party services had to be incorporated in the collection of such data. Regardless of this fact, most cooperatives supported our efforts by the successful submission of meteorological data.

The most difficult part of the data collection procedure turned up to be the submission of demographic data. Values such as the building's surface in square meters, as well as a number of residents, are very important for acquiring the normalized consumption indexes, which are necessary for the reasonable analysis and comparison of both individual customers/members, and for consumption comparison among REScoops as well. The main issue with the collection of such data is that they are not publicly available (except for rare cases, e.g. building characteristics in Denmark), and have to be retrieved with personal questionnaires sent to each individual household and business separately. Despite this fact, most REScoops submitted demographics, apart from a few cases where this was indeed impossible to get.

4. Statistical Analysis Methodology

In this section, we provide insights on the main part of this report. In particular, we describe the methods we exploited in order to conduct the statistical data analysis, the typical values that we computed, the features according to which we performed clustering of the population, and the way that we computed the reduction in various measures of interest.

Calculation of Typical Values

To begin with, we report on the calculations of typical values we performed. We have computed the average value of energy consumption in kWh for various groups, by summing over the values of all measurements and dividing by their number (sample size). Thus, the computed average values are un-weighted. Furthermore, in order to gain better insight into the energy consumption, we have also performed normalization with respect to other features, e.g., the number of residents. Such normalization is important when the monthly energy consumption in kWh greatly varies among different households due to factors like the number of inhabitants and the geographical region of residence. In that case, we just divided the kWh measurement of a data point by the value of the feature taken under consideration for normalization. In some cases, we have conducted normalization with respect to two features, e.g. Heating Degree Days (HDD) and m^2. This is performed by dividing the energy consumption measurement in kWh by the product of the values of the other features.

Specifically, we can calculate the following indices (as indicated in [5]):

- Average monthly electricity consumption in kWh normalized by Heating Degree Days (Avg. kWh/HDD)
- Average monthly heating energy consumption in kWh normalized by Heating Degree Days (Avg. kWh/HDD)
- Average half-yearly electricity consumption in kWh normalized by Heating Degree Days (Avg. kWh/HDD)
- Average yearly electricity consumption in kWh normalized by Heating Degree Days (Avg. kWh/HDD)
- Average monthly electricity consumption in kWh normalized by square meters (Avg. kWh/m^2)
- Average monthly heating energy consumption in kWh normalized by square meters (Avg. kWh/m^2)
- Average half-yearly electricity consumption in kWh normalized by square meters (Avg. kWh/m^2)
- Average yearly electricity consumption in kWh normalized by square meters (Avg. kWh/m^2)
- Average monthly electricity consumption in kWh normalized by Heating Degree Days and square meters (Avg. kWh/(HDD*m^2))
- Average monthly heating energy consumption in kWh normalized by Heating Degree Days and square meters (Avg. kWh/(HDD*m^2))
- Average half-yearly electricity consumption in kWh normalized by Heating Degree Days and square meters (Avg. kWh/(HDD*m^2))
- Average yearly electricity consumption in kWh normalized by Heating Degree Days and square meters (Avg. kWh/(HDD*m^2))
- Average monthly electricity consumption in kWh normalized by number of residents and square meters (Avg. kWh/(residents*m^2))

- Average half-yearly electricity consumption in kWh normalized by number of residents and square meters (Avg. kWh/(residents*m^2))
- Average yearly electricity consumption in kWh normalized by number of residents and square meters (Avg. kWh/(residents*m^2))

For each REScoop, we have computed a subset of the indices mentioned above, depending on the data that each of them has provided us with.

Population Division in Groups

Naturally, a sample population is not homogeneous with respect to various features. Therefore, it is meaningful to separate a population into disjoint groups and proceed in comparisons among them. In the context of our statistical analysis, the most meaningful discrimination was according to whether a consumer had received an Energy Efficiency intervention or not. However, in our statistical analysis we have also performed a number of group divisions, according to the following features:

- Cooperative and non-cooperative members
- Number of residents
- Building characteristic
    - Building has attic
    - Building has basement
    - Building has attic and basement
    - Building has neither attic nor basement
- Building insulation factor
- Previous heating source
    - Electricity
    - Natural Gas
    - Oil
    - Oil & Solar Heating
- Prosumers and non-prosumers
- Contract type
    - Residential
    - Association
    - Local authority
    - Enterprise-Commercial
    - Independent
    - Social contract
- Meteorological regions
- Energy Efficiency measure
    - Leaflets
    - Technical support
    - Software solutions
    - Engagement activities
- Tariffs
    - Special
    - Flat
    - Time of use

Note that this list is populated according to the available data that the REScoops submitted, and can be a good example for the new REScoops to adopt. However, it is not exhaustive and should be subject to change according to the guidelines provided in D2.1 and D2.2, and to data availability by each new REScoop, i.e. which measurements they store.

Reductions Calculation

In order to estimate the impact that the various measures had on energy consumption, the calculation of the reduction that was brought by their application is needed. The reductions are computed in both absolute values and percentages. Nevertheless, such computations required the estimation of the probability density of the random variable, which is related to the samples. We exploited the Kernel Density Estimation (KDE) to fulfil this goal. KDE is widely used when inferences about the population have to be made, and is closely related to histograms, but exhibits smoother behaviour. Thus, we can compute the average of a given index based on the distribution that KDE provides us with, and then proceed in the calculation of the reduction.

Analysis of Variance (ANOVA)

Variance is one of the most important measures in statistics, which gives valuable information about a dataset. Intuitively, computing the variance is equivalent to computing the expected value of the distance of each data point from the expect value of the whole dataset. In our statistical analysis, we have exploited two statistical methods, namely ANOVA [6] and Kendall's tau coefficient [7], which are closely related to variance, and provide us with valuable information regarding the impact of an index on the kWh consumption.

ANOVA essentially provides a statistical test of whether the means of different groups are different. In its simplest form, ANOVA takes under consideration a single factor, which is also named as one-way ANOVA. The simplest extension is the consideration of two factors, which is usually referred to as two-way ANOVA. Furthermore, the ANOVA test has important assumptions that must be satisfied for the associated results to be valid:

- The samples are independent.
- Each sample is generated from a normal distribution.
- Each group has the same standard deviation (homoscedasticity).

ANOVA tests provide us with a p-value, which gives information on the significance of a factor on the tested variable. Following the standard approach in the literature, we will consider a factor as significant if the associated p-value is less than 0.05.

Kendall's tau coefficient is a statistic used to measure the relationship between rankings of different ordinal variables. It can also be used in order to measure different rankings of the same variable. Being a correlation coefficient, it takes values in [-1, 1], where values close to -1 indicate negative correlation, and, respectively, values close to 1 indicate positive correlation. In our statistical tests, Kendall's tau coefficient is used in order to point out whether taking a measure has affected the kWh consumption. Thus, values close to 0 indicate that a taken measure has significantly altered the consumption. Additionally, it has to be noted that in order to compute Kendall's tau coefficient for two random variables, the number of the samples of each has to be the same.

Results Presentation

Here, we explain how the results from the preliminary analysis are presented in the rest of this deliverable. For each of the participating REScoops, we discuss the main findings in the text, and also provide analytical figures and numerical results in tables, with two purposes: First to help the reader understand from which calculations our findings come from, and second, to allow REScoop experts to draw additional conclusions, which lie beyond the scope of this WP's work, that is, to test the impact of REScoops EE interventions on members' and customers' consumption.

We describe the components in detail.

Tables with numerical values

The tables with the numerical results contain the average energy consumption indices for each population group before and after the application of certain EE interventions. Where data was available, the impact on more than one energy consumption indicator is reported and tested for significance.

Marking the result with asterisks indicate significance as shown here:

Marking	p-value
***	0.001 to 0 (extremely significant)
**	0.01 to 0.001 (very significant)
*	0.05 to 0.01 (significant)
.	0.1 to 0.05 (low, but not significant)

Also, for the calculation of CO_2 reductions, we used the typical national values of CO_2 per kWh, available in the European Environment Agency website[1].

Kernel density estimation plots

Kernel density estimation is used to estimate the probability distribution of the data samples that we have, i.e. gives a picture of the behaviour of the consumers. It can be thought of as a continuous histogram of the data samples. On the X-axis, we have the consumption values and on the Y-axis the density (number) of measurements. Lower density values denote fewer measurements, i.e. rare consumption behaviour, while higher density denotes more common behaviour among consumers. If the density changes in some consumption values after applying the EE interventions, then it is clear that the intervention had an impact on the consumer behavior. We also include the average value with a dashed vertical line, to visualize the average change as well.

Box plots and violin plots

The box plot is a popular non-parametric tool to visualize groups of numerical data and give general intuitions for their statistical characteristics. The box represents the 50% confidence interval from the median (vertical line), and asterisks above the box-plot's top "whiskers", that represent the 95% confidence interval, depict the outliers.

Now, a violin plot combines the box plot with the kernel density estimation plot; on each side of the box plot, there is a rotated kernel density plot, in a symmetrical way that reminds of a violin.

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[1]http://www.eea.europa.eu/data-and-maps/figures/co2-electricity-g-per-kwh/co2-per-electricity-kwh-fig-1_2010_qa.xls

5. Preliminary Results

In this Section, we present the results of the statistical analysis of the impacts of EE interventions on the energy demand of REScoop's clients.

5.1 EBO – Denmark

The results we present here come from 300 customers of the Danish district heating cooperatives case, those administrated by EBO.

EBO submitted the requested monthly information from their customers, from the period of 5/2012 to 9/2016. They also provided production data, however, these do not concern EBO own generators, thus were excluded from the analysis. Additionally, EBO gathered yearly consumption measurements from their customers, before joining the cooperative. This gives us a clear view of the average consumption reduction induced by their choice of becoming REScoop members. Furthermore, EBO gathered data from customers of a non-cooperative district heating company. The customers of both companies were treated with a specific EE intervention, that of technical support.

The Technical support EE intervention includes technical inspections and suggestions for equipment or insulation upgrades, etc. As numerical results illustrate, this particular EE intervention is quite effective.

Description and analysis of submitted data

No. of customers:	300
..of which cooperative members	300
..of which treated with EE intervention	142 (47.3%)
..of which non-cooperative members	1,058 (From another company)
..of which treated with EE intervention	508 (48%)
Meteorological regions:	1
Contract types:	1
Period with measurements:	5/2012-9/2016
Production data:	Yes
Additional data:	Yearly consumption before entering EBO
Groups to analyze:	Coop members, non-Coop members, Received Technical Support, Did not receive technical support

Becoming a cooperative member

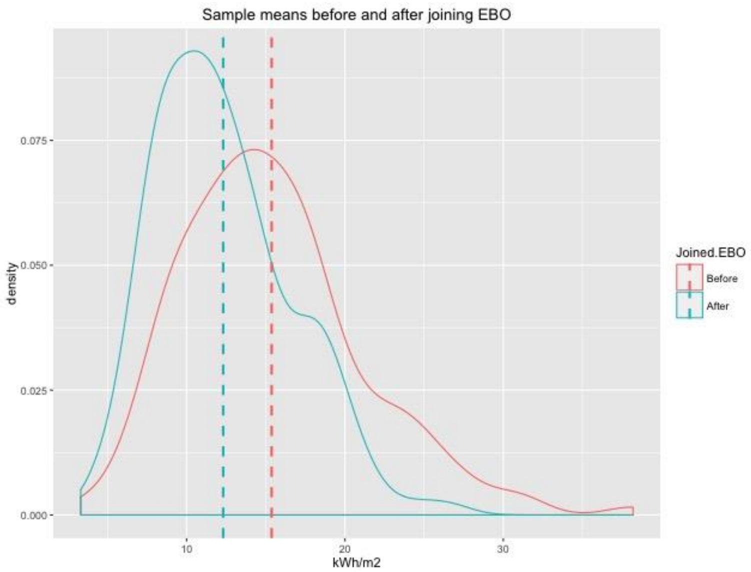

Figure 3 Kernel Density estimates of heating energy consumption samples in kWh/m^2 for all EBO members, before, and after becoming cooperative members. Dashed horizontal lines represent the average of each sample group.

Table 1 Average energy consumption values, reductions, and significance tests, before, and after joining EBO.

		Heating Energy consumption
Cooperative member	Sample size	Avg. monthly kWh/m^2
Before joining	153	15.36
After joining	153	12.30
	Reduction	3.06
	Reduction %	19.92
Estimated CO_2 reductions / typical customer (kg)		126.16
	p-value	2.402e-07 ***
	Kendall's tau	0.546

As observed in Table 1, analysis of measurements that involve 153 members indicates that these members significantly reduced their heating energy consumption (kWh/m^2) by becoming cooperative, as this value decreased by 19.92%. In Figure 3, this decrease is depicted by the vertical distance between the dashed red and blue lines, which represent the mean values of heating energy consumption expressed in terms of kWh/m^2 for the members before and after, respectively, becoming cooperative members. As seen in Figure 3, the absolute value of the reduction, which is equal to the distance mentioned above, is 3.06. Figure 3 also reveals the fact that the range of values that are above the mean value is greater compared to the one of those below it. Thus, the highest points (modes) of both distributions have values lesser than the mean values. We can also observe that cooperative members greatly reduced their average monthly CO_2 emissions production, as it decreased by 126.16 kg.

Furthermore, the ANOVA test we conducted indicates that the cooperative member index has a very significant impact on the average heating energy consumption in kWh/m², since the corresponding p-value is 2.402e-07, which is much lower than the 0.05 threshold that is taken into consideration in such tests. The validity of this observation is augmented by the value of the Kendall's tau coefficient, which is 0.546, and thus, much lower than 1.

To provide further intuitions, more figures and results are placed in the Appendix – EBO (Figures 20-23). As the analysis illustrates, becoming a cooperative member has positive impacts on consumption reductions, regardless the number of residents, and the building characteristics.

EE Intervention Application Impacts

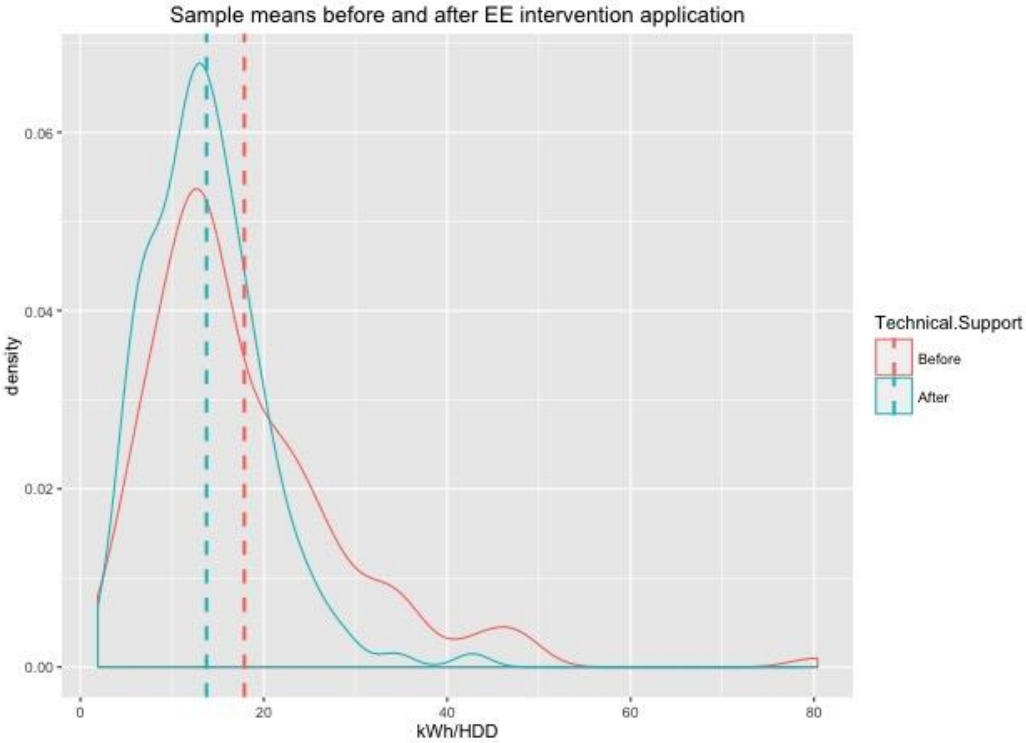

Figure 4 Kernel Density estimates of heating energy consumption samples in kWh/HDD for all EBO members, before, and after EE intervention application (Technical Support). Dashed horizontal lines represent the average of each sample group.

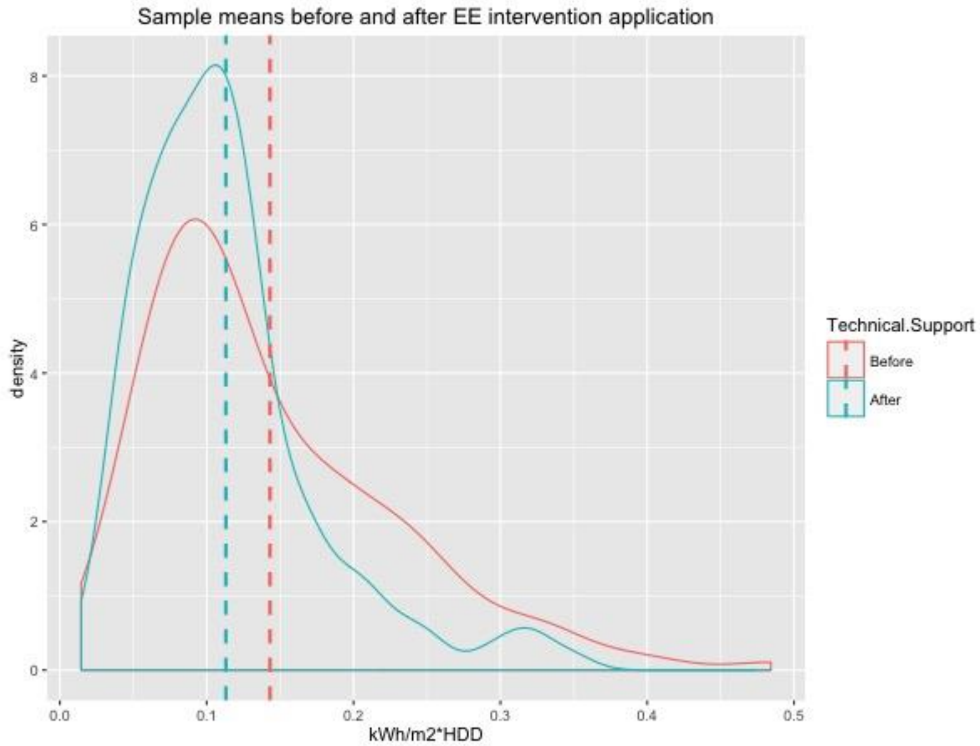

Figure 5 Kernel Density estimates of heating consumption samples in kWh/m^2*HDD for all EBO members, before, and after the EE intervention application (Technical Support). Dashed horizontal lines represent the average of each sample group.

Table 2 Average energy consumption values, reductions, and significance tests, before, and after receiving Technical Support.

		Heating Energy Consumption	
Technical Support	Sample size	Avg. kWh/HDD	Avg. kWh/(m^2*HDD)
Before application	140	17.87	0.14
After application	140	13.75	0.11
	Reduction	4.12	0.03
	Reduction (%)	20	21.42
Estimated CO_2 reductions / typical customer (kg)		274.13	
	p-value	0.0001 ***	0.0008 ***
	Kendall's tau	0.414	0.470

We observe that the 140 members that received technical support greatly reduced their heating energy consumption in both kWh/HDD (Figure 4) and kWh/(m^2*HDD) (Figure 5) expression terms. Naturally, comparing the absolute values of these reductions (Table 2), which are 4.12 for kWh/HDD and 0.03 for kWh/(m^2*HDD), is not proper, since their ranges and domains are of different scales. Nevertheless, we see that the percentage decrease of heating energy consumption in kWh/HDD is equal to 20%, and the percentage decrease of heating energy consumption in kWh/(m^2*HDD) is 21.42%. Thus, they have both great values and are quite close. A remarkable reduction of 274.13 kg of CO_2 emissions is also observed for the members that received technical support.

The technical support index is significant for heating energy consumption in both kWh/HDD and kWh/(m^2*HDD), as the corresponding values are 0.0001 and 0.0008, which are both much smaller than 0.05. Moreover, the Kendall's tau coefficients have values 0.414 and 0.470, for heating energy consumption in kWh/HDD and kWh/(m^2*HDD) respectively. Therefore, technical support plays an important role in these two types of energy consumption we studied in this case. Also, as results in the Appendix – EBO (Figures 24-26) illustrate, offering technical support is effective in most customer groups, especially for the cases that the building has a basement (more than 30% reductions).

Main Analysis Conclusions

We can conclude that both becoming a cooperative member and receiving technical support were shown to be beneficial, since our analysis shows that we observe:

- a 19.92% reduction in average heating energy consumption in kWh/m^2 (effect of becoming a cooperative member)
- a 20% reduction in average heating energy consumption in kWh/HDD (effect of receiving technical support)
- a 21.42% reduction in average heating energy consumption in kWh/(m^2*HDD) (effect of receiving technical support)

The impact of receiving technical support is greater on the CO_2 reduction than the one of becoming a cooperative member, since for the latter, it is more than the double than for the former (as 274.13 / 126.16 = 2.17).

5.2 ECOPOWER – Belgium

Description and analysis of submitted data

No. of customers:	33,600
..of which prosumers	14,464
..of which treated with EE intervention (EnergieID)	814 (5.6%)
..of which treated with EE intervention (Leaflets)	16 (0.1%)
..of which not prosumers	23,527
..of which treated with EE intervention (EnergieID)	1,010 (4.3%)
..of which treated with EE intervention (Leaflets)	1,313 (5.5%)
Meteorological regions:	1
Contract types:	3
Period with measurements:	2011-2015
Groups to analyze:	Prosumers, Contract Types, EnergieID treatment, EE leaflets treatment

As seen in the table above, a great number of the members of ECOPOWER are prosumers, i.e., they both produce and consume energy. Specifically, the percentage of the total number of cooperative members that are prosumers is 43.04%. Furthermore, ECOPOWER has applied two EE intervention measures, namely EnergieID (software) and information leaflets for the cases of over-consuming customers. Further, ECOPOWER offers 3 contract types.

Furthermore, as results in Appendix – ECOPOWER indicate, there are many significant factors impacting energy consumption, e.g. having production capabilities, the contract type, the number of residents, and the year of measurements (Figures 27-29). Although the first three are trivial, the last one deserves noting: the consumption of ECOPOWER customers is reduced as the years go by. This is mainly due to the increasing production that prosumers achieve, year by year (Figures 30-33).

Becoming a cooperative member

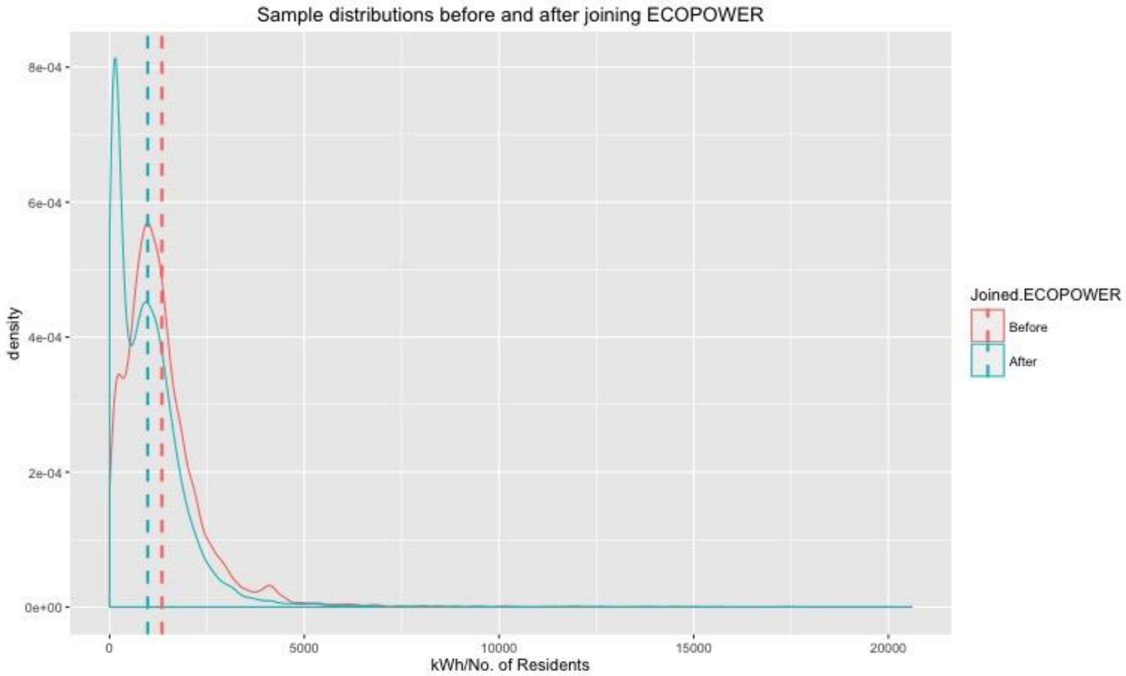

Figure 6 Kernel Density estimates of electricity consumption samples in kWh/No. of Residents for all ECOPOWER members, before, and after becoming a cooperative member. Dashed horizontal lines represent the average of each sample group.

Table 3 Average energy consumption values, reductions, and significance tests, before, and after joining ECOPOWER.

		Electricity Consumption			
Cooperative member	Sample size	Avg. yearly kWh	Avg. yearly kWh/No. of Residents	Sample size	Avg. yearly kWh/m^2
Before joining	10,653	3,146.38	1,343.47	357	18.55
After joining	10,653	2,219.21	977.51	357	14.31
	Reduction	927.14	365.96		4.24
	Reduction (%)	29.46	27.23		22.85
	Estimated CO_2 reductions / typical customer (kg)	235.12			
	p-value	2.2e-16 ***	2.2e-16 ***		7.74e-06 ***
	Kendall's tau	0.326	0.422		0.404

As seen in Table 3, we have conducted analysis on 10,653 annual measurements regarding electricity consumption expressed in terms of kWh and kWh/No. of Residents. The sample size of yearly electricity consumption in kWh/m^2 was 357, since this is the number for which we had data regarding m^2. Despite that the reduction in electricity consumption in kWh/No. of Residents caused by members joining ECOPOWER, presented in Figure 6 might seem small at first sight, as the dashed lines appear to be quite close, this is not true, as we can observe in Table 3 that the percentage reduction of electricity consumption in kWh/No. of Residents is equal to 27.23%. The reason that Figure 6 appears to depict a smaller reduction is that the range of values in the distributions is large, but extreme values on the upper tail have tiny probability. Furthermore, the reduction in yearly electricity consumption in kWh is even greater, since members who joined ECOPOWER consumed 29.46% (Table 3) less than before becoming cooperative members. The reduction in average annual electricity consumption (in kWh/m^2) is also greater than 20%; 22.85% in precise.

Having observed the percentage reductions in the indices mentioned above caused by the members' joining the RESCoop, it is not surprising that the ANOVA tests indicate that the factor of being a cooperative member has a major impact on all of those indices, since the greatest corresponding p-value is only 7.74e-06. This is also confirmed by Kendall's tau coefficient values, which range from 0.422 to 0.326, thus being close to 0 (denoting high significance) for every index.

Becoming a prosumer

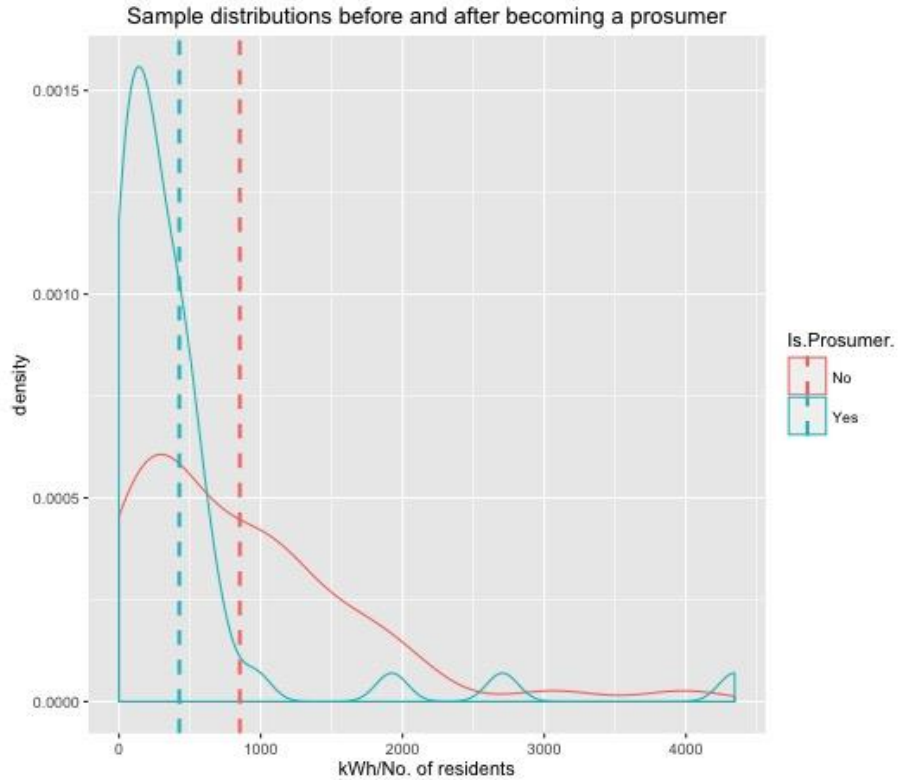

Figure 7 Kernel Density estimates of electricity consumption samples in kWh/No. of Residents for all ECOPOWER members, before, and after becoming prosumers. Dashed horizontal lines represent the average of each sample group.

Table 4 Average consumption values, reductions, and significance tests, before, and after becoming a prosumer.

		Electricity Consumption			
Becoming a prosumer	Sample size	Avg. yearly kWh	Avg. yearly kWh/No. of Residents	Sample size	Avg. yearly kWh/m^2
Before production capabilities	2,295	2,267.79	852.44	144	11.91
After production capabilities	2,295	1,120.17	425.65	144	6.45
Reduction		1,147.62	426.79		5.46
Reduction (%)		50.60	50.06		45.84
Estimated CO_2 reductions / typical customer (kg)		291.03			
p-value		3.725e-05 ***	0.006 **		5.587e-09 ***
Kendall's tau		0.318	0.238		0.418

In Table 4, we observe statistics regarding the electricity consumption of cooperative members before and after they were able to not only consume, but produce as well. We conducted analysis on the indices of yearly electricity consumption in kWh and kWh/No. of Residents, having a sample size of 2,295 data points. The percentage reduction was very close for both indices, as it was 50.60% of yearly electricity consumption in kWh and 50.06% of yearly electricity consumption in kWh/No. of Residents. The low p-values (3.725×10^{-5} and 0.006) estimated by the ANOVA test, consist indicators of the high impact that being a prosumer has on yearly electricity consumption values in kWh and kWh/No. of Residents. The values of Kendall's tau coefficient are 0.318 for kWh and 0.238 for the kWh/No. of Residents index, and as these values are much lower than the value of 1, they confirm our conclusions regarding the significance of being a prosumer in consumption reduction.

Furthermore, we were given 144 data points regarding yearly electricity consumption in kWh/m^2. We have computed that the percentage reduction caused by the effect of becoming prosumer was great for this index also, as its value is 45.84%. Both the p-value (5.587×10^{-9}) returned by performing the ANOVA test and the value of Kendall's tau coefficient (0.418) suggest that becoming a prosumer was a statistically significant measure.

EE Intervention Application Impacts (EnergieID)

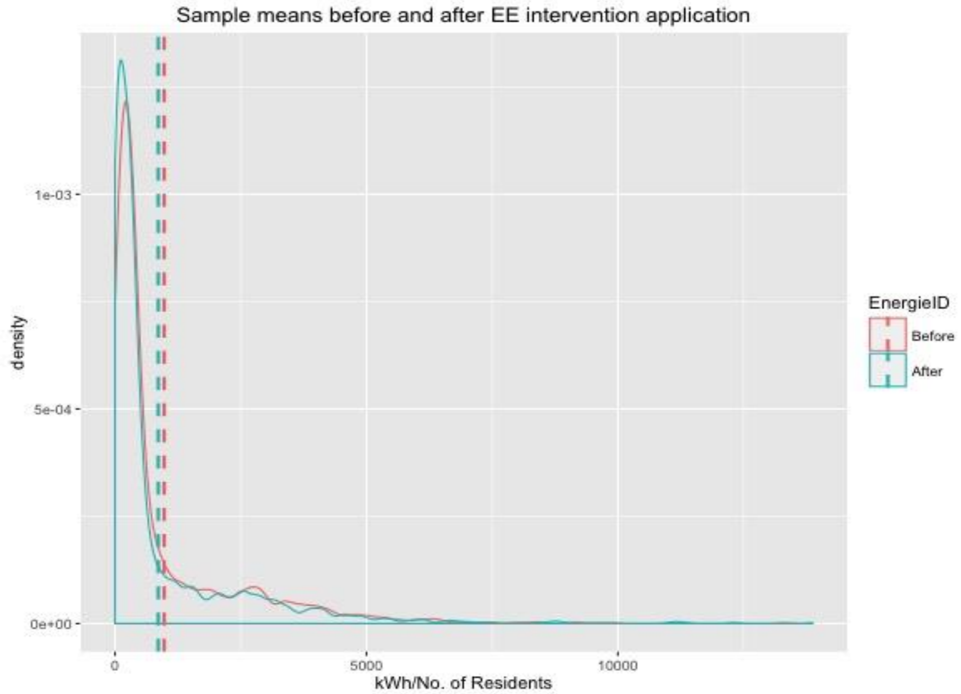

Figure 8 Kernel Density estimates of electricity consumption in kWh/No. of Residents samples for all ECOPOWER members, before, and after registering to EnergieID. Dashed horizontal lines represent the average of each sample group.

Table 5 Average consumption values, reductions, and significance tests, before, and after registering for EnergieID.

		Electricity Consumption			
EnergieID	Sample size	Avg. yearly kWh	Avg. yearly kWh/No. of Residents	Sample size	Avg. yearly kWh/m^2
Before registration	1,805	2,364.43	978.55	1,249	14.23
After registration	1,805	2,094.32	861.40	1,249	12.71
Reduction		270.11	117.15		1.52
Reduction (%)		11.42	11.97		10.68
Estimated CO_2 reductions / typical customer (kg)		68.49			
p-value		0.0003***	0.015 *		0.004 **
Kendall's tau		0.716	0.728		0.721

In Table 5 we can see that the adoption of the EE intervention measure of EnergieID contributed to reduce annual electricity consumption (expressed in kWh) by approximately 11.42%, since the same members consumed 2,094.32 kWh yearly when they became cooperative compared to 2,364.43 when they were not. The yearly electricity consumption in kWh/No. of Residents was reduced by almost the same rate (11.97%). EnergieID had a significant impact on both kWh and kWh/No. of Residents indices, as the corresponding p-values of the ANOVA test, were 0.0003 and 0.015, which are both less than 0.05. We observe that the values of the Kendall's tau coefficient are not as low as they are in the case we examined the effect of prosumers, but they are still significantly lower than 1; 0.714 and 0.728 for kWh and kWh/No. of Residents, respectively.

Moreover, we performed data analysis on 1,249 samples regarding electricity consumption in kWh/m^2. As observed in Table 5, we found that the application of EnergieID caused an overall reduction of 10.68% on that index. Furthermore, the p-value returned by the ANOVA test and the value of the Kendall's tau coefficient are quite close to those of the kWh and kWh/No. of Residents (in which cases we had 1,764 samples). Therefore, EnergieID had a significant impact on kWh/m^2 too.

We must note that the EnergieID EE measure was highly more effective on prosumers (since the results in Appendix – Ecopower (Figures 34, 35) indicate that mere consumers did not manage to reduce after their subscription) and that it has positive impacts on contract types A, and C.

Main Analysis Conclusions

To sum up, becoming a prosumer has had the greatest positive effect on consumption reduction since it has led to 50.06% reduction in yearly electricity consumption in kWh/No. of Residents and 45.84% reduction in yearly kWh/m^2. Both becoming a cooperative member and a prosumer have led to significant reduction of CO_2 produced, namely 235.12 and 291.03 kg, respectively. Also, registering to the EnergieID software induced more than 10% reduction in every energy consumption index that we examined.

Note that, the analysis regarding the application of the EE leaflets intervention is inconclusive (as seen in the Appendix).

5.3 ENERCOOP – France

Description and analysis of submitted data

No. of customers:	14,561
..of which cooperative members	4,936
..of which treated with EE intervention (Dr. Watt)	39 (0.79%)
..of which not cooperative members	9,625
..of which treated with EE intervention (Dr. Watt)	19 (0.19%)
Meteorological regions:	5
Contract types:	5
Period with measurements:	1/2015-4/2016
Groups to analyze:	Cooperative members, Contract types, Smart Meters, Meteorological Regions, Dr. Watt, Means of Heating-Types

Our dataset for ENERCOOP consists of data for 14,561 customers, where about one-third of them are a cooperative member (4,936/14,561 = 0.34). However, only 39 cooperatives and 19 non-cooperative members have been treated with EE intervention, namely Dr. Watt (software). The customers are divided into 5 meteorological regions, while ENERCOOP offers 5 distinct types of contract. The measurements on which we conducted data analysis are taken over a period of more than a year (1/2015 – 4/2016).

As the results in Appendix – Enercoop further indicate (Figures 39-47), the factors impacting customers' consumption is the contract type, the meteorological region, the cooking method that tenants use, as well as the heating method. Being a cooperative member and possessing smart meters do not influence the consumption distributions significantly.

EE Intervention Application Impacts (Dr. Watt)

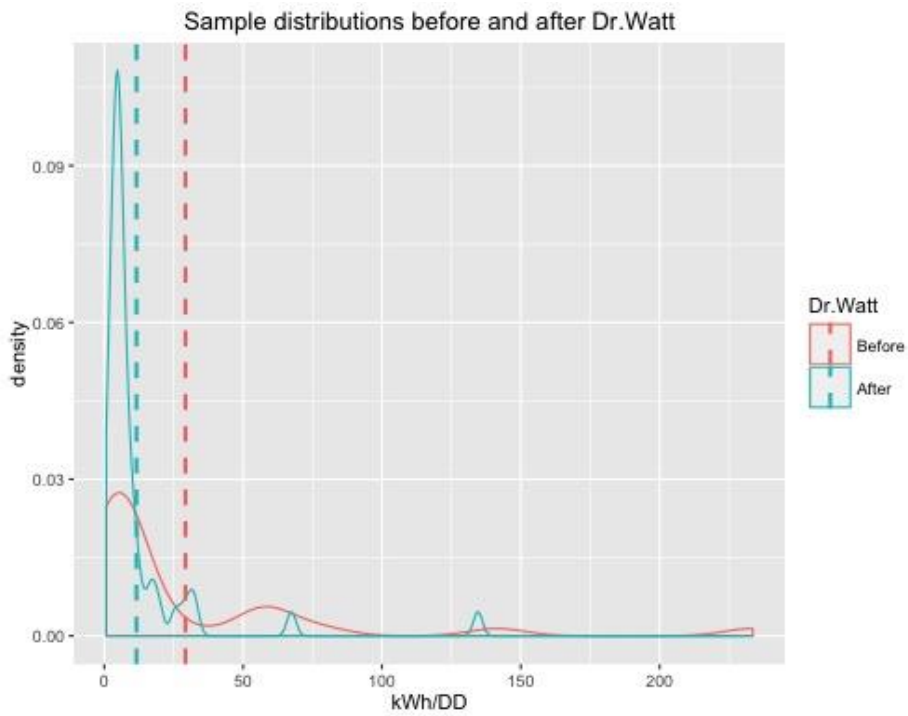

Figure 9 Kernel Density estimates of electricity consumption samples in kWh/Degree Day for all ENERCOOP members, before, and after becoming registering for Dr. Watt. Dashed horizontal lines represent the average of each sample group.

Table 6 Average consumption values, reductions, and significance tests, before, and after registering for Dr Watt.

		Electricity Consumption
Dr. Watt	Sample size	Avg. 6-monthly kWh/DD
Before subscription	28	29.23
After subscription	53	11.60
	Reduction	17.63
	Reduction (%)	60.31
	Estimated CO_2 reductions / typical customer (kg)	405.08
	p-value	0.031 *

From Table 6, we observe that we have a sample size of 28 customers subscripting to Dr. Watt, and of 53 customers after the subscription to Dr. Watt took place. As the results show, the 6-monthly kWh/DD percentage reduction was 60.31%, indicating the great success of the measure. The ANOVA test returned a p-value of 0.031, which confirms the significance and positive results that the application of Dr. Watt brought.

Main Analysis Conclusions

From the analysis we have conducted, we can conclude that the application of Dr. Watt has led to very positive results, as it caused a percentage reduction of 60.31% on average monthly electricity consumption in kWh/DD and 405.08 kg less CO_2 emissions per customer.

5.4 SOMENERGIA – Spain

Description and analysis of submitted data

No. of customers:	12,495
..of which cooperative members	8,475
..of which treated with EE intervention (Smart meter)	7,612 (89.8%)
..of which treated with EE intervention (Gen. active)	458 (5.4%)
..of which treated with EE intervention (Emp. active)	31 (0.36%)
..of which not cooperative members	4,021
..of which treated with EE intervention (Smart meter)	3,489 (86.7%)
..of which treated with EE intervention (Gen. active)	78 (1.93%)
..of which treated with EE intervention (Emp. active)	13 (0.32%)
Meteorological regions:	43
Contract types:	2
Period with measurements:	4/2015-4/2016
Groups to analyze:	Cooperative members, Contract types, Smart Meters, Generation active, Empowering active

The number of its customers, which is equal to 12,495, indicates that SOMENERGIA is a large REScoop. More than two of thirds of are cooperative members, since 8,475/12,495 = 0.67. Moreover, three EE intervention measures were applied, namely the Smart meter, Generation active, and Empowering active. The customers were characterized by 43 meteorological regions and 2 contract types, while the period of measurements was one year and one month (4/2015 – 4/2016).

As the additional results in Appendix – Somenergia indicates factors such as the contract type, cooperative membership, and tariff type have significant impacts on the consumption of SOMENERGIA's customers.

Installing Smart Meters

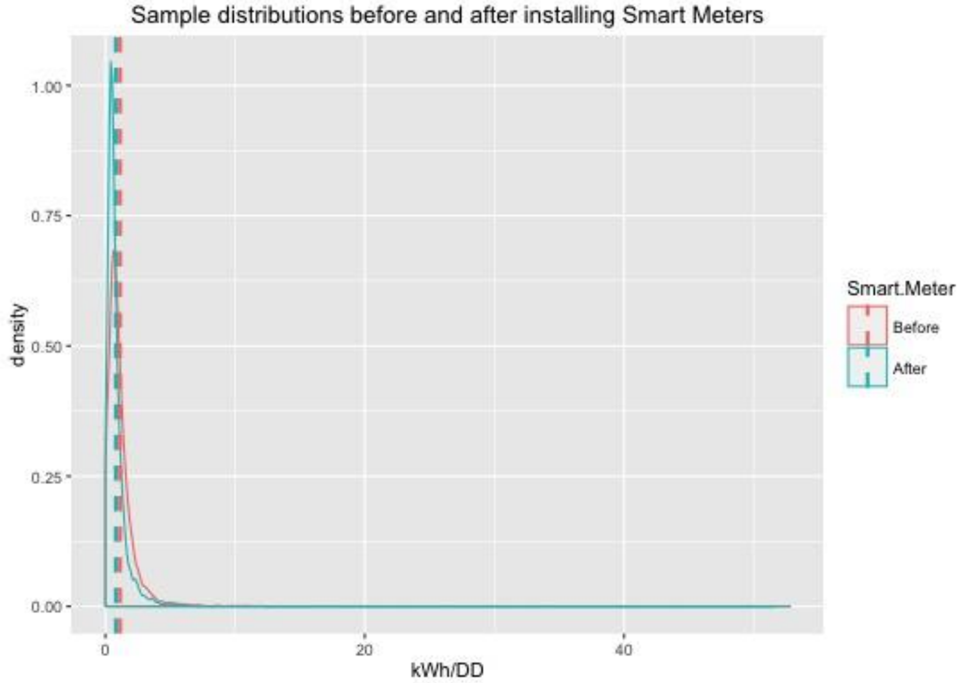

Figure 10 Kernel Density estimates of electricity consumption samples in kWh/Degree Day for all SOMENERGIA members, before, and after installing Smart Meters. Dashed horizontal lines represent the average of each sample group.

Table 7 Average consumption values, reductions, and significance tests, before, and after installing Smart Meters.

		Electricity Consumption
Smart Meters	Sample size	Avg. monthly kWh/DD
Before installation	6,283	1.13
After installation	6,283	0.80
	Reduction	0.33
	Reduction (%)	29.20
	Estimated CO_2 reductions / typical customer (kg)	27.26
	p-value	< 2.2e-16 ***
	Kendall's tau	0.657

The total number of customers who installed Smart Meters was 6,283, as observed in Table 8. We have observed a significant percentage reduction regarding electricity consumption per DD (kWh/DD), as its value is 29.20%. Both the p-value (< 2.2×10^{-16}) returned by the ANOVA test, and the value of Kendall's tau coefficient (0.657), suggest that the installation of Smart Meters was statistically significant for the monthly electricity consumption in kWh/DD consumption.

Installing smart meters have positive impacts on the reduction of energy consumption regardless the customer group being applied (see Appendix – Somenergia, Figures 50-52).

EE Intervention Application Impacts (Generation Active)

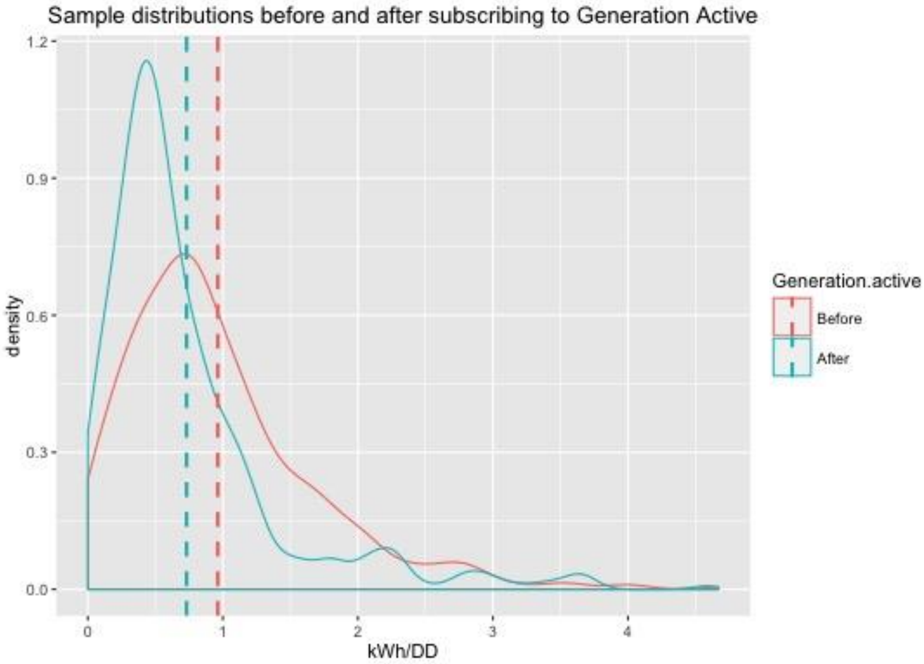

Figure 11 Kernel Density estimates of electricity consumption samples in kWh/Degree Day for all SOMENERGIA members, before, and after registering for Generation Active. Dashed horizontal lines represent the average of each sample group.

Table 8 Average consumption values, reductions, and significance tests, before, and after registering for Generation Active.

		Electricity Consumption
Generation Active	Sample size	Avg. monthly kWh/DD
Before Subscription	513	0.96
After Subscription	513	0.73
	Reduction	0.23
	Reduction (%)	23.95
	Estimated CO_2 reductions / typical customer (kg)	19.51
	p-value	1.181e-07 ***
	Kendall's tau	0.676

After conducting a statistical analysis regarding the subscription to Generation Active for 513 measurements, we observed a similar phenomenon that appeared in the analysis regarding the installation of Smart Meters. As observed in Table 8, the percentage change in electricity consumption, expressed in kWh per DD, was positive (23.95%). Thus, it appears that normalizing by DD is important for the measurements in the SOMENERGIA REScoop. The reduction in kWh/DD caused by subscribing to Generation Active is also obvious in Figure 11, where the red and blue dashed lines are considerably distant. Furthermore, the p-value estimated by the ANOVA test is 1.181 x 10^{-7} which indicates that the subscription to Generation Active is statistically significant for the index of monthly kWh/DD. The value of the Kendall's tau coefficient is 0.676, and is thus not close to 1, confirming the impact of the EE intervention measure of subscribing to Generation Active on the monthly kWh/DD.

By the additional results shown in Appendix – Somenergia (Figures 53-55), we can conclude that the Generation Active EE intervention measure has positive impacts on consumption reductions for all customer groups.

Main Analysis Conclusions

We can conclude that the installation of Smart Meters and becoming Generation Active have been both beneficial, as they caused 29.20% and 23.95% reduction on kWh/DD, respectively. However, we need more data in order to assess the effect of becoming Empowering Active, since we had only 44 average monthly consumption data points using this intervention, which are simply not enough for a meaningful statistical analysis (see Appendix – Somenergia for a preliminary attempt to such an analysis).

5.5 ENOSTRA – Italy

Description and analysis of submitted data

No. of customers:	150
Meteorological regions:	4
Contract Types	1
Period with measurements:	3/2016-8/2016
Production data:	No (But a few available prosumer data)
Missing data:	No EE applied (only special tariffs already implemented)
Groups to analyze:	Consumers and prosumers per tariff type, and heating and cooking methods

Now, we provide statistics for ENOSTRA, which has only 150 customers in total, divided into 4 meteorological regions. The measurements correspond to a period of 6 months (3/2016 – 8/2016), and no EE intervention measure has been applied.

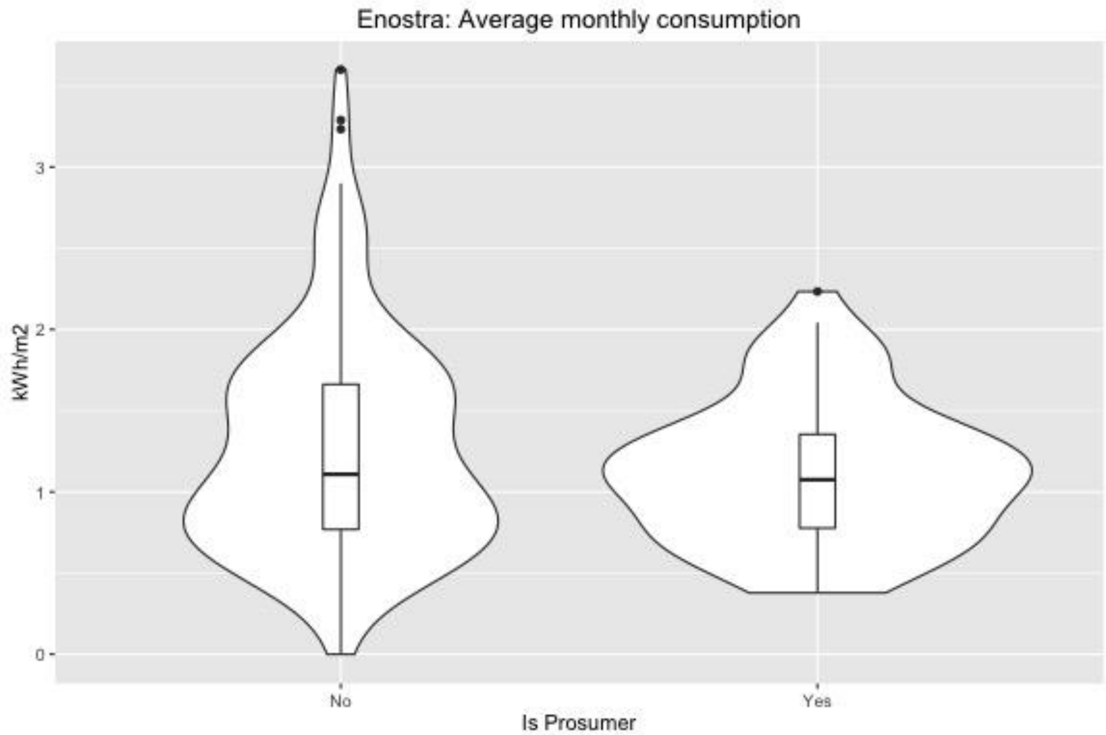

Figure 12 Violin plots for electricity consumption in kWh/m^2 samples for all ENOSTRA members, categorized by production capabilities.

Table 9 Sample sizes and average values for ENOSTRA members.

		Electricity Consumption			
Is Prosumer	Sample size	Avg. kWh	Avg. kWh/HDD	Avg. kWh/m^2	Avg. kWh/No. of Residents
No	833	137.84	0.64	1.27	52.15
Yes	61	134.63	0.56	1.12	51.85
	p-value	0.775	0.313	0.105	0.952

In Figure 12, we present the violin plot of average monthly electricity consumption in kWh/m^2 of non-prosumer and prosumer members. Comparing the corresponding two distributions, we observe that the one that corresponds to prosumers has a much greater mass close to 1, while the one that corresponds to non-prosumers has a broader range, especially towards large values, even greater than 3, of consumption.

In Table 9, we observe that the majority of measurements is regarding non-prosumers, since the corresponding sample size is 833, while the sample size for prosumer measurements is only 61. However, for all indices taken into consideration, being a prosumer implies that reduction in consumption. In particular, the average kWh for prosumers (134.63) is just a bit less than the one of the non-prosumers (134.63). However, the percentage difference is greater when kWh/HDD is taken into consideration, as for non-prosumers it is valued to 0.64 and for prosumers to 0.56. In the same manner, we see that both the kWh/m^2 and kWh/No. of Residents are less for prosumers than for non-prosumers.

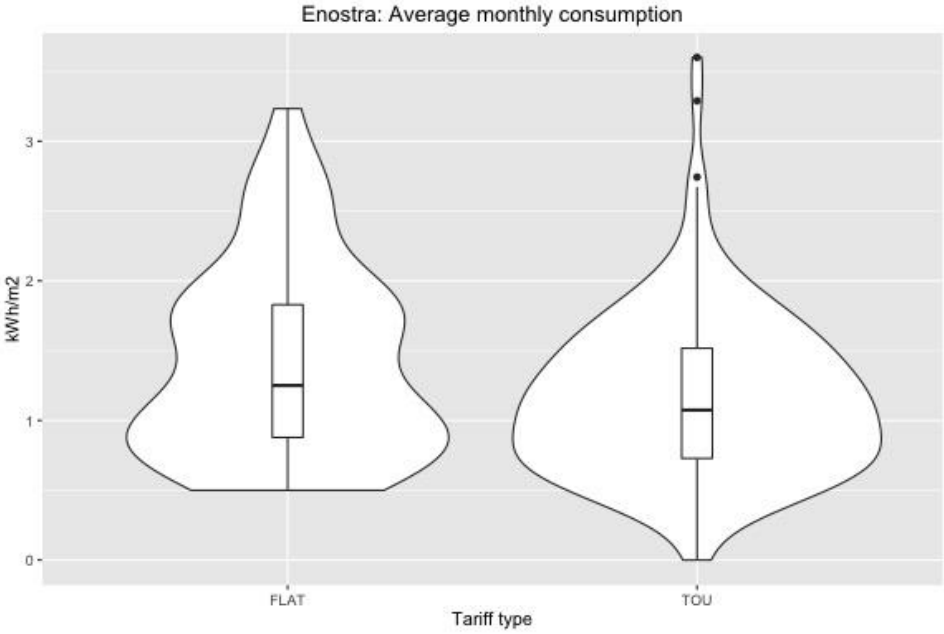

Figure 13 Violin plots for electricity consumption in kWh/m^2 samples for all ENOSTRA members, categorized by Tariff types.

Table 10 Sample sizes and average values for ENOSTRA members.

		Electricity Consumption			
Tariff type	Sample size	Avg. kWh	Avg. kWh/DD	Avg. kWh/m^2	Avg. kWh/No. of Residents
FLAT	336	136.32	0.67	1.42	56.46
TOU	552	136.67	0.60	1.16	50.48
	p-value	0.668	0.025 *	0.008 **	0.253

In Table 10, we see that the monthly electricity consumption in kWh is not significantly different for members that are on the standard rate (FLAT) and Time of Use (TOU) tariff types, since 136.32 is almost equal to 136.67. This is also depicted by the corresponding distributions indicated by the violin plots in Figure 13. Nevertheless, normalizing by DD, m^2, and No. of Residents we observe some significant reductions caused by subscribing in tariff type TOU. Specifically, the reduction in kWh/DD is 0.07 (=0.67-0.60), while the reduction in kWh/m^2 is 0.26 (=1.42-1.16). Similarly, we observe a significant reduction (5.98=56.46-50.48), in kWh/No. of Residents.

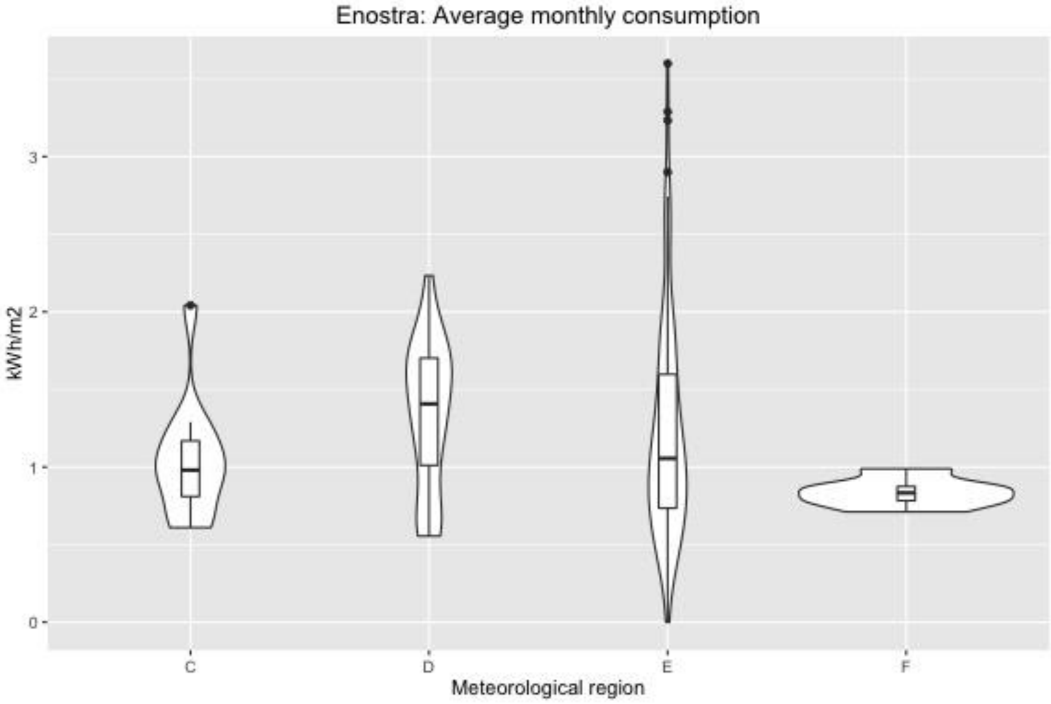

Figure 14 Violin plots for electricity consumption samples in kWh/m² for all ENOSTRA members, categorized by meteorological region.

Table 11 Sample sizes and average values for ENOSTRA members.

		Electricity Consumption			
Meteorological region	Sample size	Avg. kWh	Avg. kWh/DD	Avg. kWh/m²	Avg. kWh/No. of Residents
C	48	98.50	0.50	1.03	93.25
D	180	126.68	0.63	1.34	53.74
E	624	144.69	0.66	1.21	48.29
F	42	124.33	0.52	0.83	37.66
	p-value	0.0003 ***	0.082	0.156	4.472e-05 ***

In Table 11, we compare the effect of 4 meteorological regions on the indices of kWh, kWh/DD, kWh/m² and kWh/No. of residents. We observe that the consumers residing in region E had the greatest kWh consumption (144.69), while those residing in region D consumed (126.68) about the same as those residing in region E (124.33). The kWh/DD index ranges from 0.50 (meteorological region C) to 0.66 (meteorological region E). One significant difference we observe is on the kWh/m² index, where the residents of region D consume about 60% more than the ones of region F, since 1.34/0.83 = 1.61. Looking at the last column of Table 11, we observe another interesting difference, since the consumers residing in region C consume about 2.5 times kWh/No. of residents what customers in region F consume, since 93.25/37.66 = 2.47.

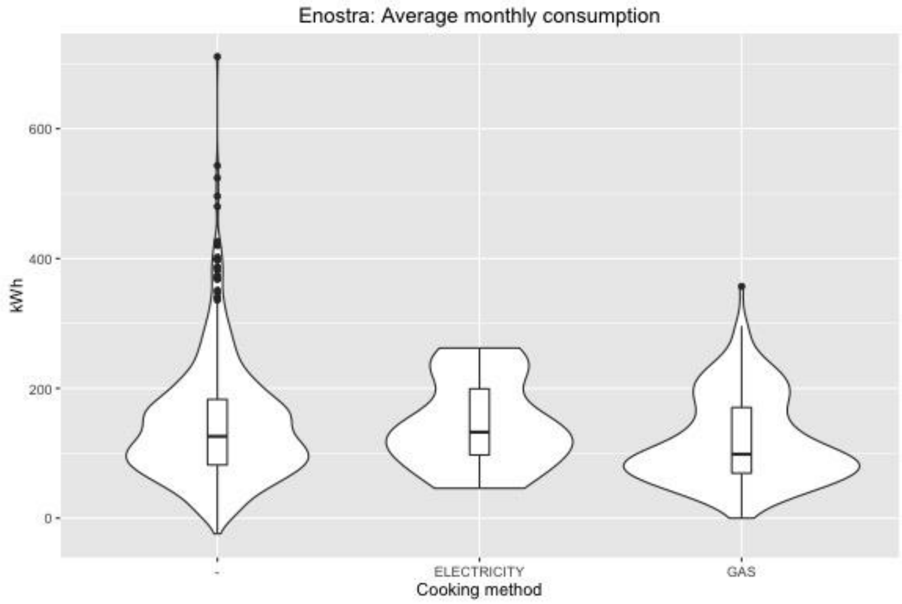

Figure 15 Violin plots for electricity consumption samples in kWh/m² for all ENOSTRA **members, categorized by cooking method.**

Table 12 Sample sizes and average values for ENOSTRA members.

		Electricity Consumption			
Cooking method	Sample size	Avg. kWh	Avg. kWh/DD	Avg. kWh/m²	Avg. kWh/No. of Residents
-	690	142.36	0.66	-	-
ELECTRICITY	18	143.88	0.60	1.10	69.56
GAS	186	119.46	0.55	1.24	50.37
	p-value	0.004 **	0.066	0.378	0.017 *

In Table 12, we observe the consumption differences regarding a number of indices with respect to the cooking method. First, we see that the vast majority of the measurements are for gas, since that sample size is 186 which much greater to the corresponding one for electricity (18). The only index for which the consumption is greater when gas is used is the kWh/m² consumption. However, since cooking is taken into consideration, the most meaningful index, in this case, is the kWh/No. of Residents. We observe that electricity causes about 38% more consumption, with respect to this index, since 69.56/50.37 = 1.38. As it is expected, gas appears to be saving electricity consumption.

Main Analysis Conclusions

The results from our statistical analysis indicate that:

- The Time of Use (TOU) tariff type is more beneficial to the standard rate (FLAT) regarding customers' consumption reduction.
- It is not clear which meteorological region has the greatest effect on consumption, as the ranking of the regions varies according to different indices.

- Using gas instead of electricity for cooking results to substantially reduced electricity consumption.

5.6 COOPERNICO - Portugal

The case of COOPERNICO is that of a very newly formed REScoop, thus there are not large consumption datasets available yet, neither have any EE interventions have been applied so far. Thus, we only present the consumption distribution of COOPERNICO members, that summarizes the submitted dataset. Figure 16 presents the Kernel Density Estimate, and Table 15 the sample size and the average monthly electricity consumption in kWh of the members with contract type A.

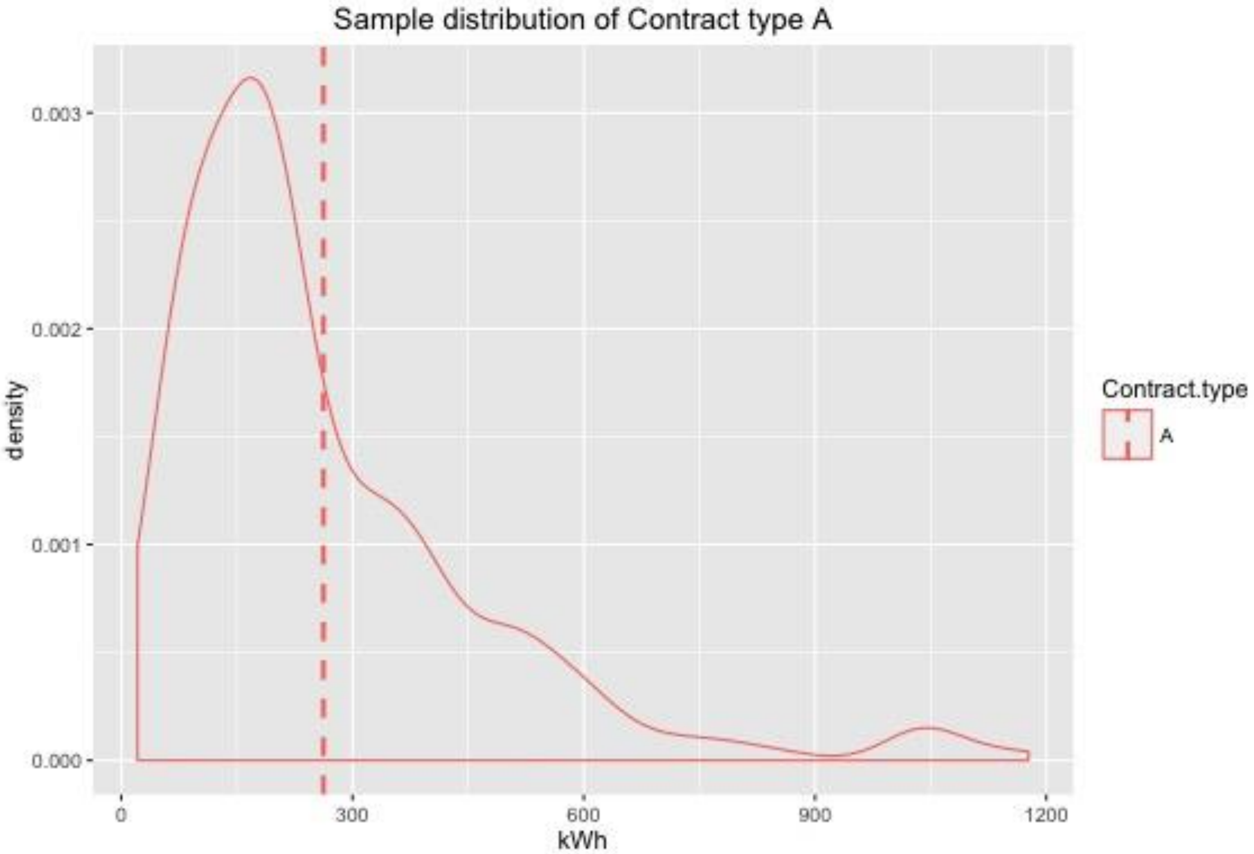

Figure 16 Kernel Density estimate of kWh consumption samples for all COOPERNICO members of contract type A. The dashed horizontal line represents the average of the sample group.

Table 13 Sample size and average consumption for COOPERNICO members.

		Electricity consumption
Contract type	Sample size	Avg. monthly kWh
A	292	262.22

More results regarding the COOPERNICO case will be available later on in the project's lifetime.

6. Conclusions

In this deliverable, we presented the statistical analysis methodology and its results on the datasets that the collaborating REcoops provided. To conclude, we now provide a review of the lessons learned and the success stories that come up from our results.

Energy usage data collection, sharing, and analysis is not a trivial task for REScoops. The absence of connected smart metering equipment, in many cases, makes it imperative to use DSO/ Transmission System Operator (TSO) collected, which however often come in a different data format and time granularity.

The collection of credit demographic data, in particular, although hard to get due to privacy legislation, it is crucial for the calculation of the indices that the EC requests, i.e. yearly kWh/m^2. It is imperative to get access to this data, even in the form of REScoop-wide average values. In the cases where this was not available, our analysis used other normalized indices commonly used in the literature, such as Degree Days, and the number of residents. We note that the Degree Days used in our calculations were computed and provided by the REScoops (as opposed to being typical estimated national values).

Overcoming the challenges, in this WP, TUC managed to collect and analyse data of a substantial size, from six (6) different REScoops (and not just four as necessitated by the project agreement). The success stories that clearly emerge are the following:

- Joining a REScoop leads to reductions in energy demand, specifically more than 20% reduction in consumption per member, on average, as results from the analysis of two different REScoop cases.
- Given the 20% reduction estimate above, and taking into account that the REScoops under examination have approximately 76,000 customers in total, it can be deduced (though this is, of course, an informal, though pessimistic given our observed estimate) that the formation of these REScoops has resulted to prohibiting a total of 1,529 tonnes of CO_2 per month, from spreading into the earth's atmosphere.
- Becoming a prosumer, i.e. having the ability to also produce energy, substantially reduces REScoop members' electricity demand, specifically more than 45% reduction in different consumption indexes.
- Subscribing to consumption monitoring and savings suggestions software platforms results in approximately 35% consumption reduction on average, as accrues from the analysis of data from two different REScoop cases.
- Performing successful EE interventions of various types, such as technical support, special tariffs, energy generation schemes, installing smart meters, leads to substantial reductions as measured in various consumption indices: Specifically, technical support lead to 20% reductions in kWh/HDD (see section 5.1), special tariffs show 22% reductions in kWh/m^2 (see section 5.5), energy generation schemes show 24% in kWh/DD (see section 5.4), and smart meter installation shows 29.20% reduction in kWh/DD (see section 5.4).

As a final note, it is imperative that participating REScoops continue the storing of data in the agreed format throughout the duration of the REScoop Plus project, as this is necessary for the successful conduction of the final statistical analysis to be presented in deliverable D2.4.

References

[1] RESCOOP Plus *Project Proposal*, H2020-EE-2015-3-MarketUptake, 2015
[2] Best practices on Renewable Energy Self-consumption, Accompanying Document, *Delivering a New Deal for Energy Consumers*, COM(2015) 339 final.
[3] REScoop Plus Project, *Deliverable D2.1-Zero Point Report on Data of Supplying REScoops*, 2016.
[4] REScoop Plus Project, *Deliverable D2.2-Methodology for Analysis*, 2016.
[5] Lohmann G, Heilmann G, Hacke U, Robinson S. *THE ICT PSP METHODOLOGY FOR ENERGY SAVING MEASUREMENT-A common deliverable from projects of ICT for sustainable growth in the residential sector.* Bonn: eSESH consortium, BECA project, co-funded by the European Commission, public project deliverable. 2011.
[6] Morris H. DeGroot and Mark J. Schervish, *Probability and Statistics (4th Edition)*, Addison-Wesley, 2010, ISBN 0-321-50046-6.
[7] Dr. Peter Y. Chen, Dr. Paula M. Popovich. *Correlation: Parametric and Nonparametric Measures (Sage University Papers series on Quantitative Applications in the Social Sciences),* Sage, 2002

APPENDIX

EBO

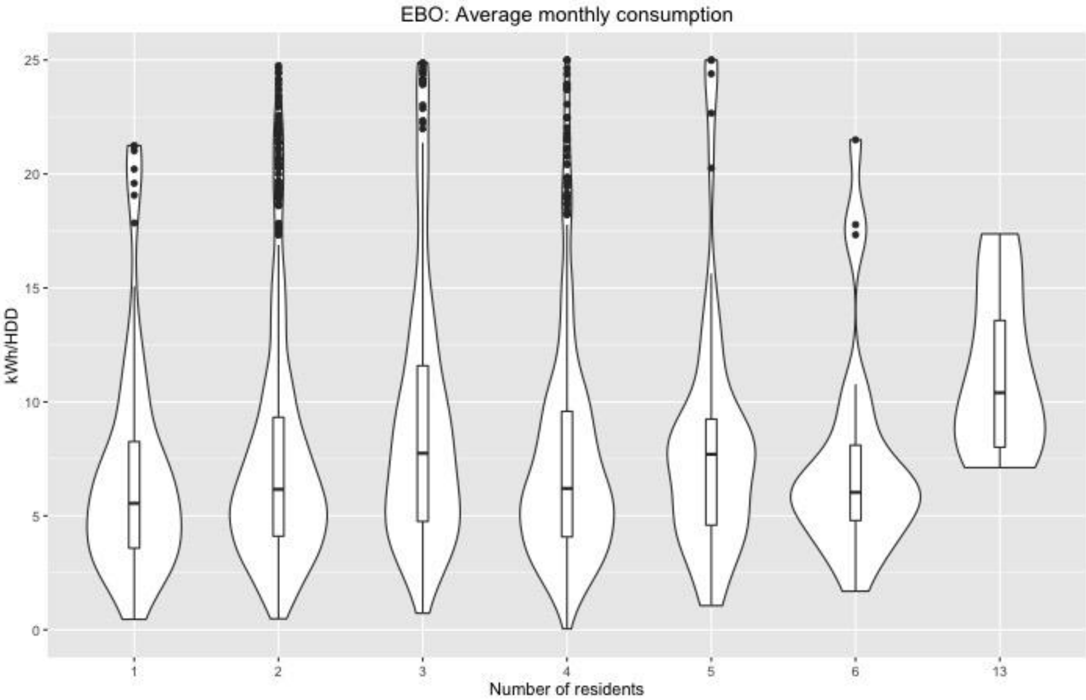

Figure 17 Without outliers with more than 25 kWh/HDD consumption

Table 14 Average energy consumption of EBO members (including outliers)

Number of residents	Sample size	Avg. kWh/HDD	Avg. kWh/m^2	Avg. kWh/(HDD*m^2)
1	94	11.17	12.26	0.10
2	1,124	15.85	10.59	0.12
3	332	21.44	12.77	0.16
4	840	16.33	11.15	0.13
5	69	13.10	9.04	0.07
6	27	9.36	8.35	0.06
13	24	40.66	13.85	0.23
	p-value	0.004 **	0.001 **	0.064

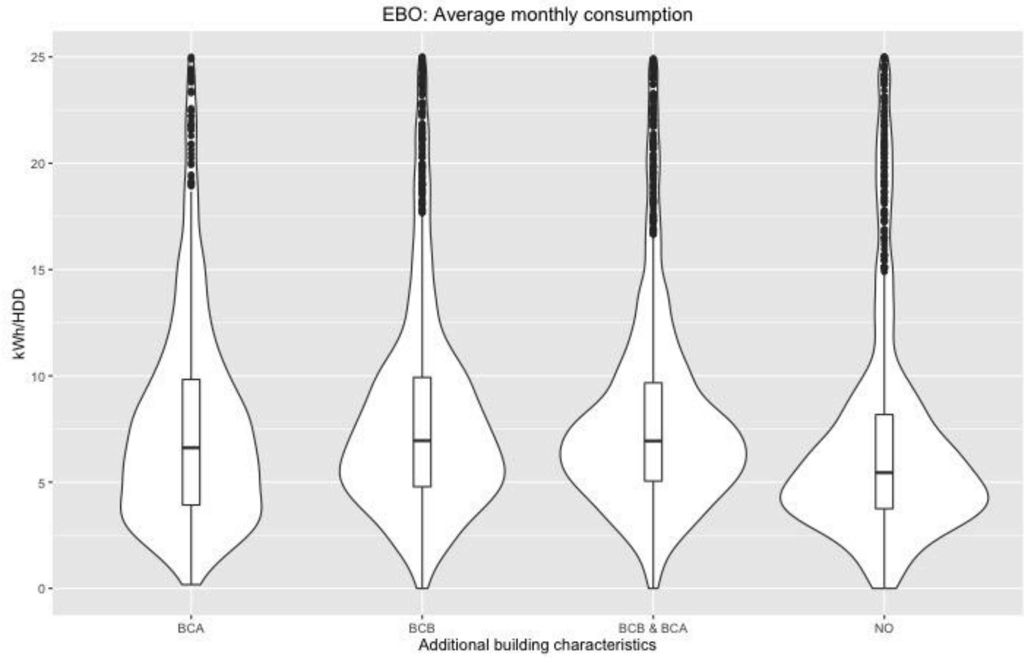

Figure 18 Without outliers with more than 25 kWh/HDD consumption (BCA: Building has an attic. BCB: Building has basement, BCB & BCA: Building has attic and basement, NO: Building does not have either).

Table 15 Average consumption of EBO members (including outliers)

Building Characteristic	Sample size	Avg. kWh/HDD	Avg. kWh/m^2	Avg. kWh/(HDD*m^2)
BCA	1004	14.11	9.25	0.08
BCB	2468	19.43	16.01	0.18
BCB&BCA	3030	17.56	12.74	0.13
NO	1778	13.89	9.41	0.11
	p-value	2.216e-06 ***	< 2.2e-16 ***	< 2.2e-16 ***

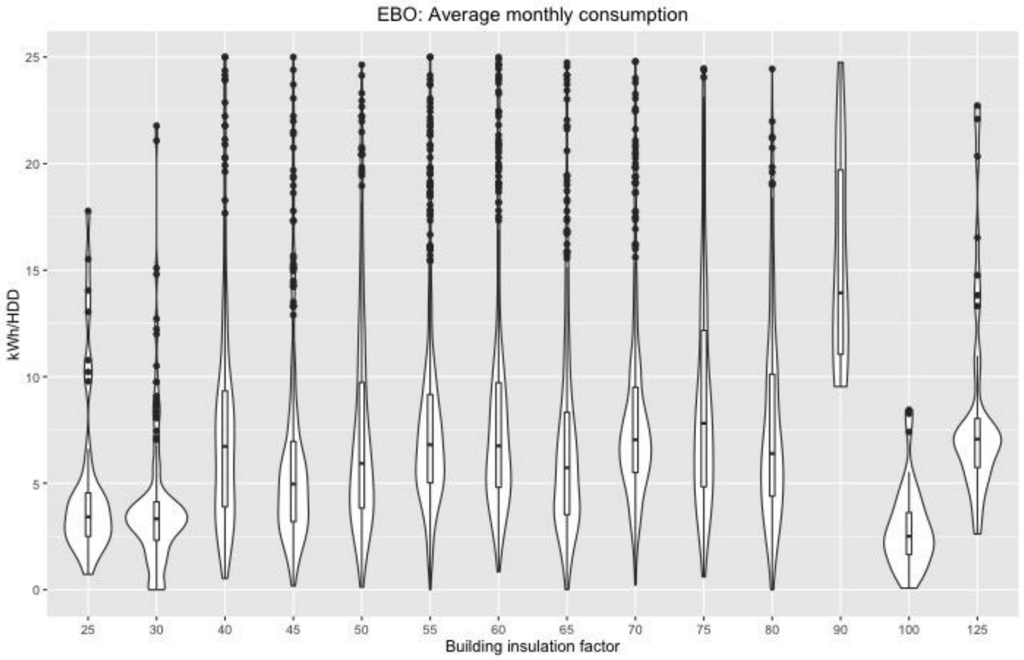

Figure 19 Without outliers with more than 25 kWh/HDD consumption (Lower insulation factor means better insulation)

Table 16 Average consumption of EBO members (including outliers)

Building insulation factor (W/m^2)	Sample size	Avg. kWh/HDD	Avg. kWh/m^2	Avg. kWh/(HDD*m^2)
25	43	7.99	6.21	0.05
30	174	5.77	5.05	0.04
40	334	15.26	9.42	0.10
45	326	10.62	7.33	0.08
50	447	15.73	9.60	0.11
55	738	16.07	12.53	0.13
60	485	18.80	12.73	0.15
65	508	13.41	11.20	0.11
70	605	20.61	13.67	0.17
75	231	22.17	13.54	0.17
80	262	17.70	14.34	0.15
90	22	54.26	21.67	0.32
100	45	2.87	3.02	0.01
125	49	18.15	15.91	0.18
	p-value	1.607e-11 ***	< 2.2e-16 ***	3.43e-11 ***

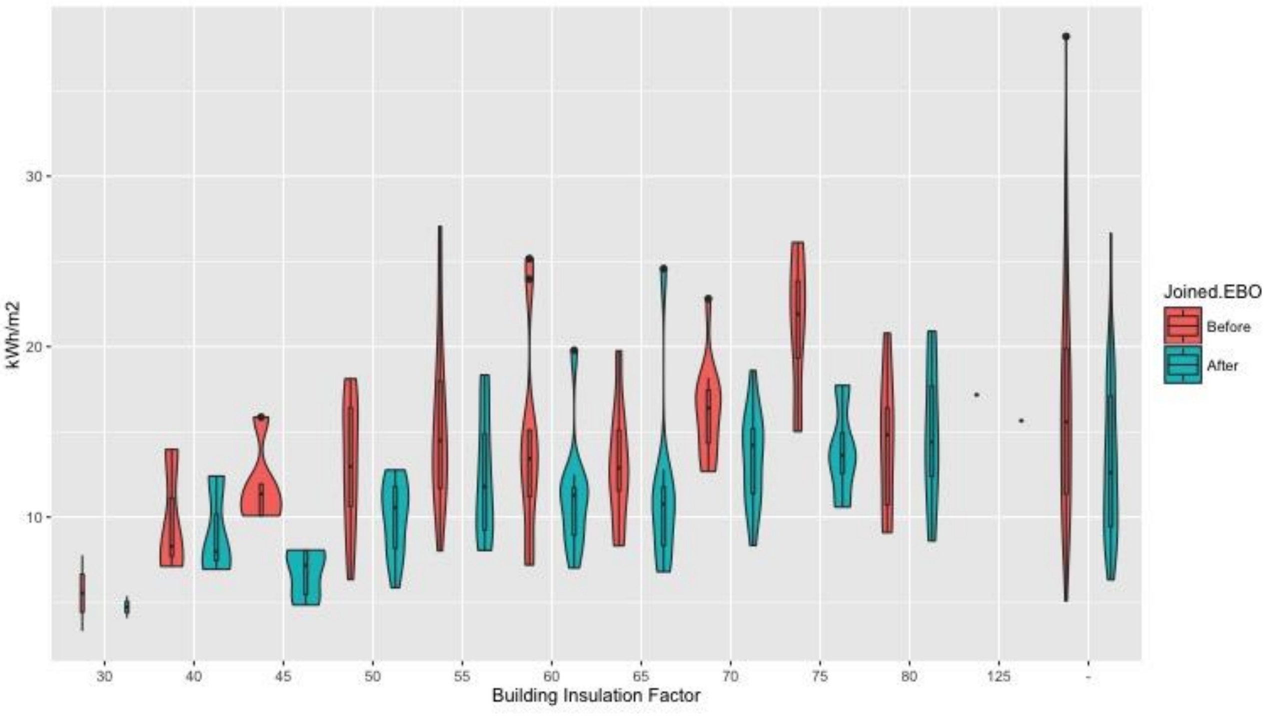

Figure 20 Violin plots before, and after joining EBO for each group per building insulation factor (W/m^2).

Table 17 Average consumption (kWh/HDD) of EBO members per building insulation factor group, before, and after joining EBO.

Building insulation factor (W/m^2)	Sample size	Joined EBO	Avg. kWh/HDD	Reduction	Reduction %
30	2	Before	5.53	0.81	14.64%
		After	4.72		
40	3	Before	9.78	0.68	6.95%
		After	9.10		
45	5	Before	11.86	5.15	43.42%
		After	6.71		
50	14	Before	13.14	3.14	23.89%
		After	10.00		
55	14	Before	15.31	2.89	18.87%
		After	12.42		
60	10	Before	14.38	3.16	21.97%
		After	11.22		
65	9	Before	13.11	1.59	12.12%
		After	11.52		
70	12	Before	16.24	2.78	17.11%
		After	13.46		
75	4	Before	21.24	7.36	34.65%
		After	13.88		
80	6	Before	14.30	-0.5	-3.49%
		After	14.80		
125	1	Before	17.17	1.52	8.85%
		After	15.65		
-	73	Before	16.55	3.39	20.48%
		After	13.16		
p-value: 3.188e-06 ***		6.345e-08***			

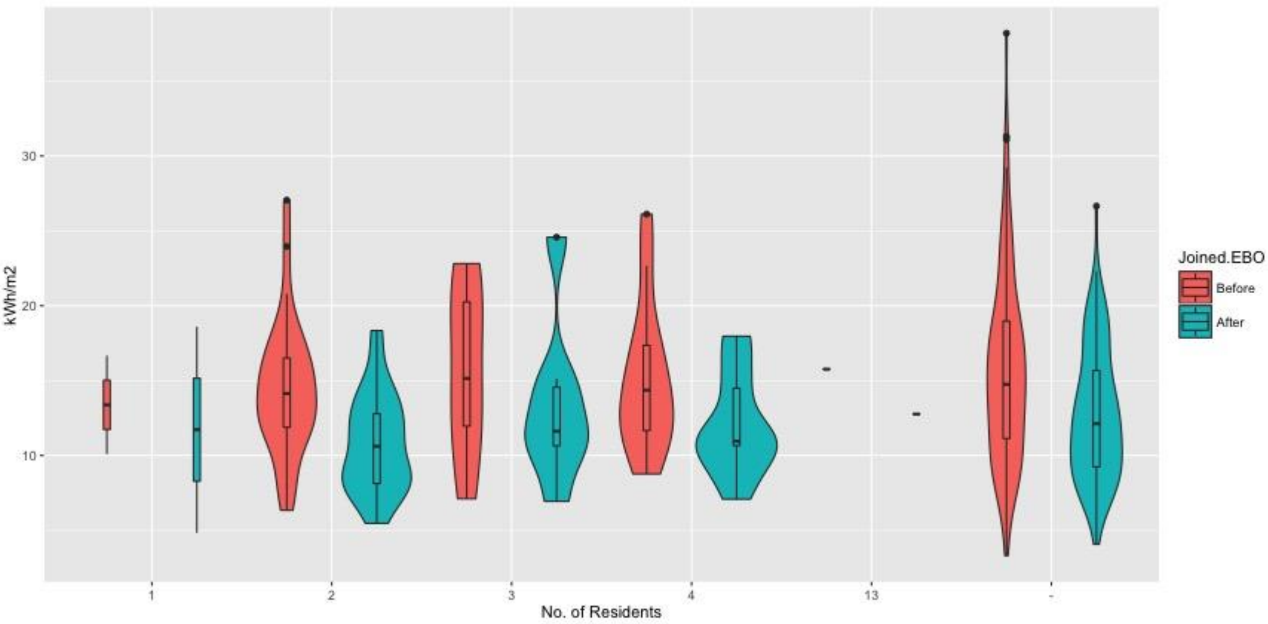

Figure 21 Violin plots before, and after joining EBO for each group per number of residents.

Table 18 Average consumption (kWh/HDD) of EBO members per number of residents group, before, and after joining EBO.

Number of residents	Sample size	Joined EBO	Avg. kWh/HDD	Reduction	Reduction %
1	2	Before	13.37	1.65	12.34%
		After	11.72		
2	30	Before	14.46	3.69	25.51%
		After	10.77		
3	7	Before	15.64	2.28	14.57%
		After	13.36		
4	13	Before	15.07	3.06	20.30%
		After	12.01		
13	1	Before	15.76	3.00	19.03%
		After	12.76		
-	100	Before	15.69	2.95	18.80%
		After	12.74		
p-value: 0.001 **		2.978e-07 ***			

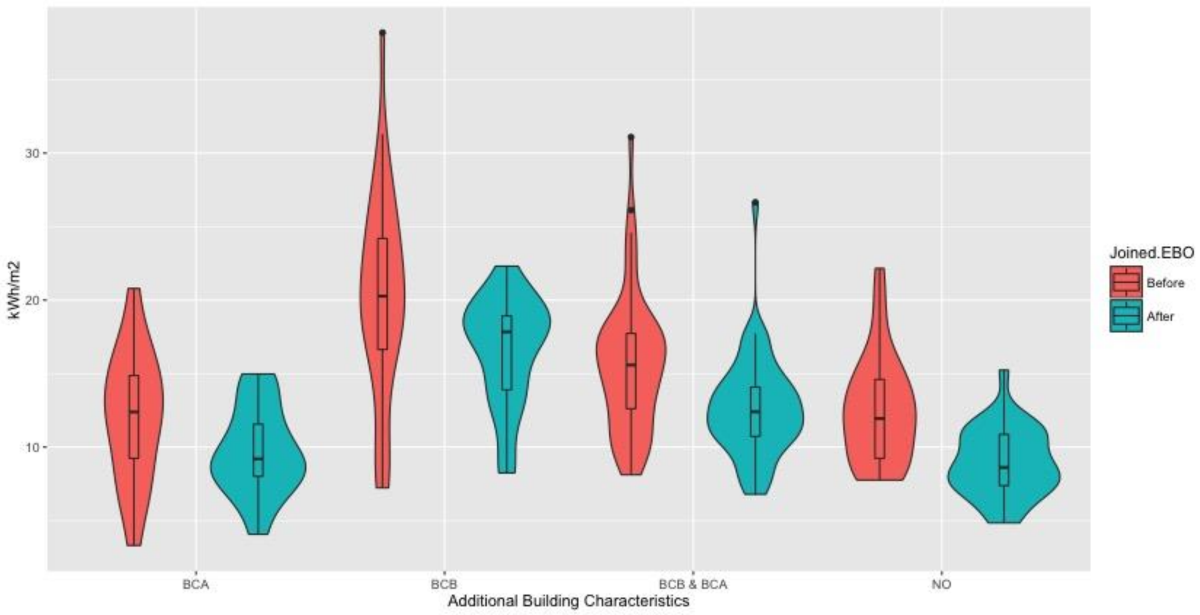

Figure 22 Violin plots before, and after joining EBO for each group per additional building characteristics.

Table 19 Average consumption (kWh/HDD) of EBO members per additional building characteristics group, before, and after joining EBO.

Building Characteristic	Sample size	Joined EBO	Avg. kWh/HDD	Reduction	Reduction %
BCA	18	Before	12.08	2.45	20.28%
		After	9.63		
BCB	32	Before	20.34	3.80	18.68%
		After	16.54		
BCB&BCA	51	Before	15.65	3.06	19.55%
		After	12.59		
NO	29	Before	12.51	3.56	28.45%
		After	8.95		
p-value: < 2.2e-16 ***		2.215e-09 ***			

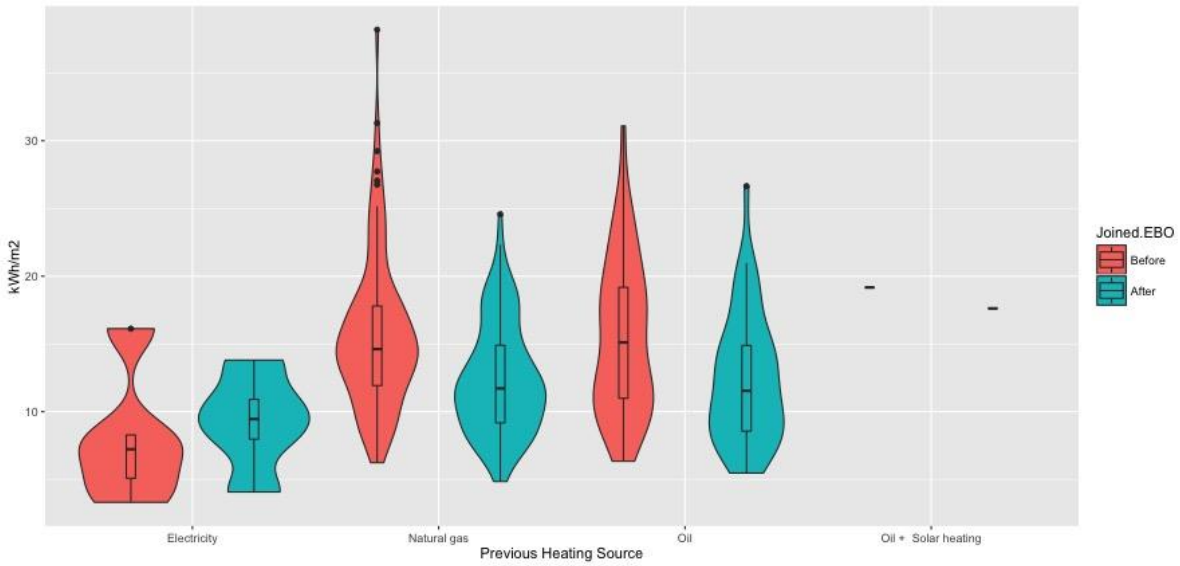

Figure 23 Violin plots before, and after joining EBO for each group per previous primary heating source.

Table 20 Average consumption (kWh/HDD) of EBO members per previous heating source group, before, and after joining EBO.

Previous Heating Source	Sample size	Technical Support	Avg. kWh/HDD	Reduction	Reduction %
Electricity	5	Before	8.00	-1.24	-15.5%
		After	9.24		
Natural Gas	102	Before	15.66	3.28	20.94%
		After	12.38		
Oil	45	Before	15.42	3.06	19.84%
		After	12.36		
Oil + Solar Heating	1	Before	19.16	1.54	8.03%
		After	17.62		
p-value: 0.005 **		1.656e-07 ***			

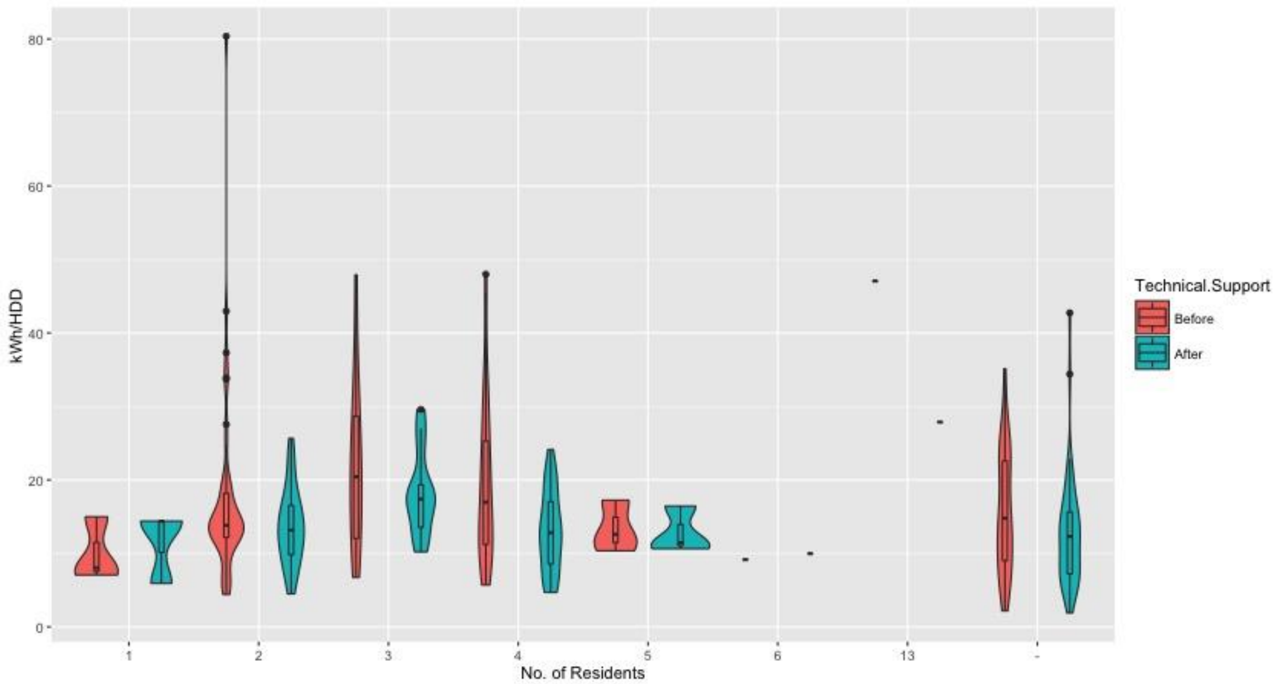

Figure 241 Violin plots, before, and after Technical Support, for each group per number of residents.

Table 21 Average consumption (kWh/HDD) of EBO members per number of residents group, before, and after Technical Support application

Number of residents	Sample size	Technical Support	Avg. kWh/HDD	Reduction	Reduction %
1	3	Before	10.02	-1.54	-15.36%
		After	11.56		
2	45	Before	17.27	3.58	20.72%
		After	13.69		
3	13	Before	22.00	3.83	17.40%
		After	18.17		
4	30	Before	19.62	6.59	33.58%
		After	13.03		
5	3	Before	13.39	0.55	4.10%
		After	12.84		
6	1	Before	9.15	-0.82	-8.96%
		After	9.97		
13	1	Before	47.05	19.19	40.78%
		After	27.86		
-	44	Before	15.84	3.01	19.00%
		After	12.83		
p-value: 0.0001 ***		0.0012 **			

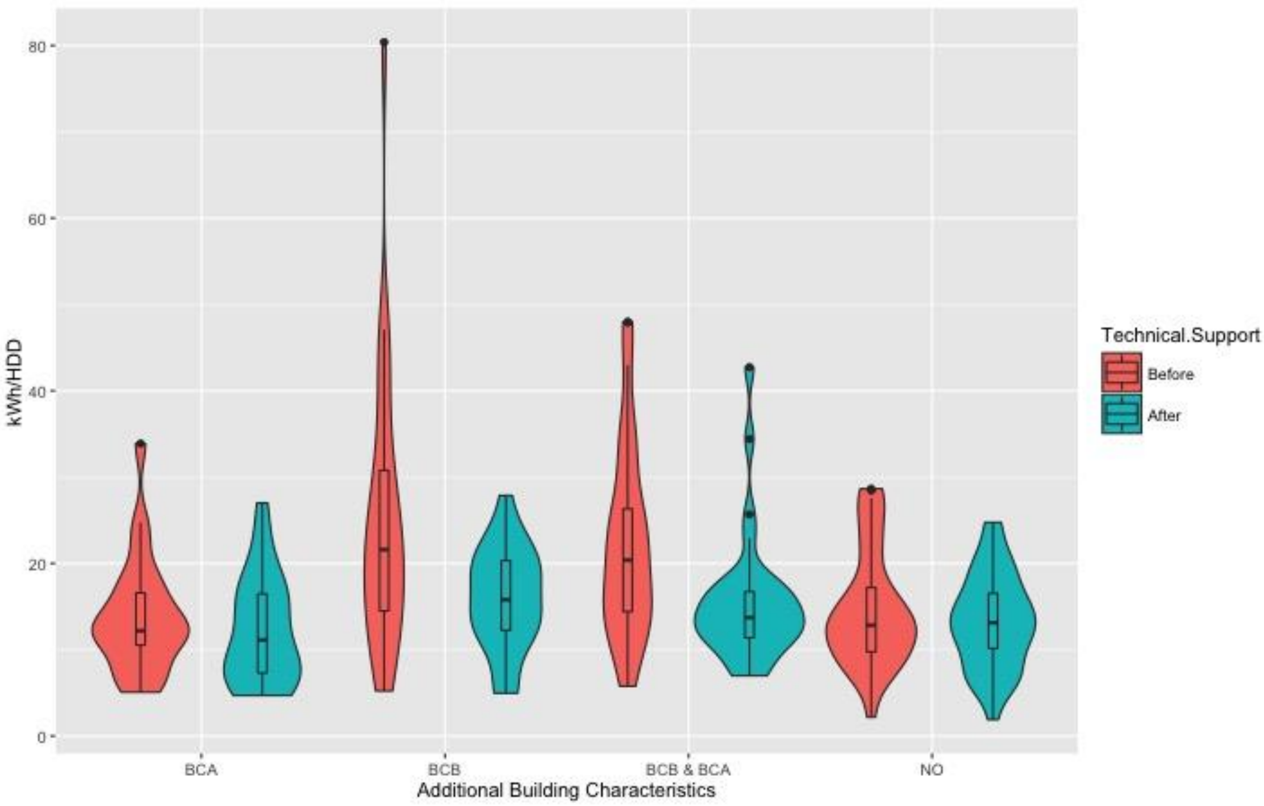

Figure 252 Violin plots before, and after receiving Technical Support for each group per additional building characteristics.

Table 22 Average consumption (kWh/HDD) of EBO members per additional building characteristics group, before, and after Technical Support application

Building Characteristic	Sample size	Technical Support	Avg. kWh/HDD	Reduction	Reduction %
BCA	23	Before	13.88	1.78	12.82%
		After	12.10		
BCB	25	Before	24.92	9.1	36.51%
		After	15.82		
BCB&BCA	32	Before	22.16	6.7	30.23%
		After	15.46		
NO	37	Before	14.57	1.32	9.05%
		After	13.25		
p-value: 7.0e-06 ***		9.317e-05 ***			

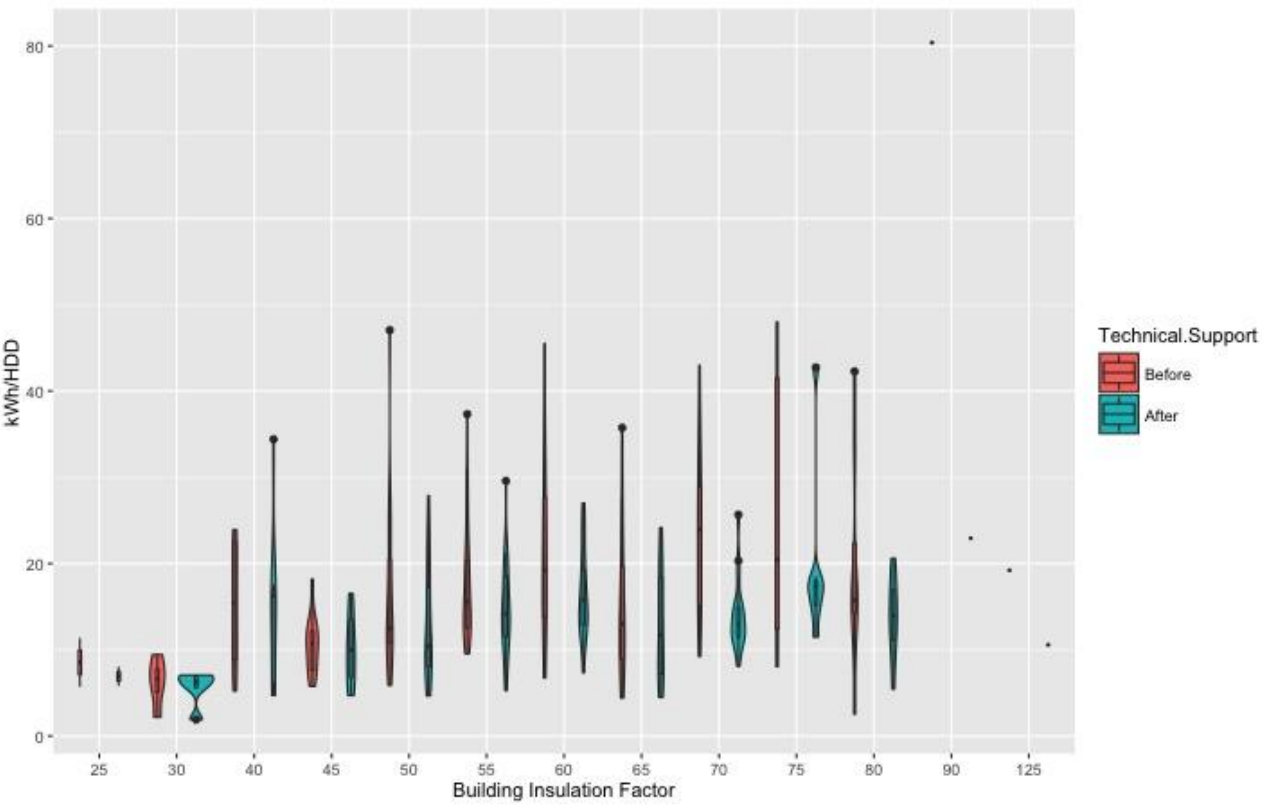

Figure 263 Violin plots before, and after receiving Technical Support for each group per building insulation factor (W/m^2).

Table 23 Average consumption (kWh/HDD) of EBO members per building insulation factor group, before, and after Technical Support application

Building insulation factor (W/m^2)	Sample size	Technical Support	Avg. kWh/HDD	Reduction	Reduction %
25	2	Before	8.52	1.61	18.89%
		After	6.91		
30	5	Before	6.21	0.65	10.46%
		After	5.56		
40	9	Before	15.01	0.53	3.53%
		After	14.48		
45	13	Before	10.53	0.55	5.22%
		After	9.98		
50	18	Before	16.03	2.89	18.02%
		After	13.14		
55	26	Before	17.64	2.98	16.89%
		After	14.66		
60	17	Before	20.65	4.11	19.90%
		After	16.54		
65	14	Before	14.97	2.15	14.36%
		After	12.82		
70	17	Before	23.36	9.36	40.06%
		After	14.00		
75	7	Before	26.33	6.65	25.25%
		After	19.68		
80	8	Before	19.44	5.69	29.26%
		After	13.75		
90	1	Before	80.38	57.46	71.48%
		After	22.92		
125	1	Before	19.21	8.65	45.02%
		After	10.56		
p-value: 1.49e-13 ***		1.512e-05 ***			

ECOPOWER

Table 24 Average consumption of ECOPOWER members

Group	Sample Size	Avg. kWh	Avg. kWh/No. of Residents	Sample Size	Avg. kWh/m^2
Prosumers	49731	1024.46	297.03	2419	6.74
Not Prosumers	67716	3026.04	1350.51	3502	18.66
p-value		<2.2e-16 ***	<2.2e-16 ***		<2.2e-16 ***

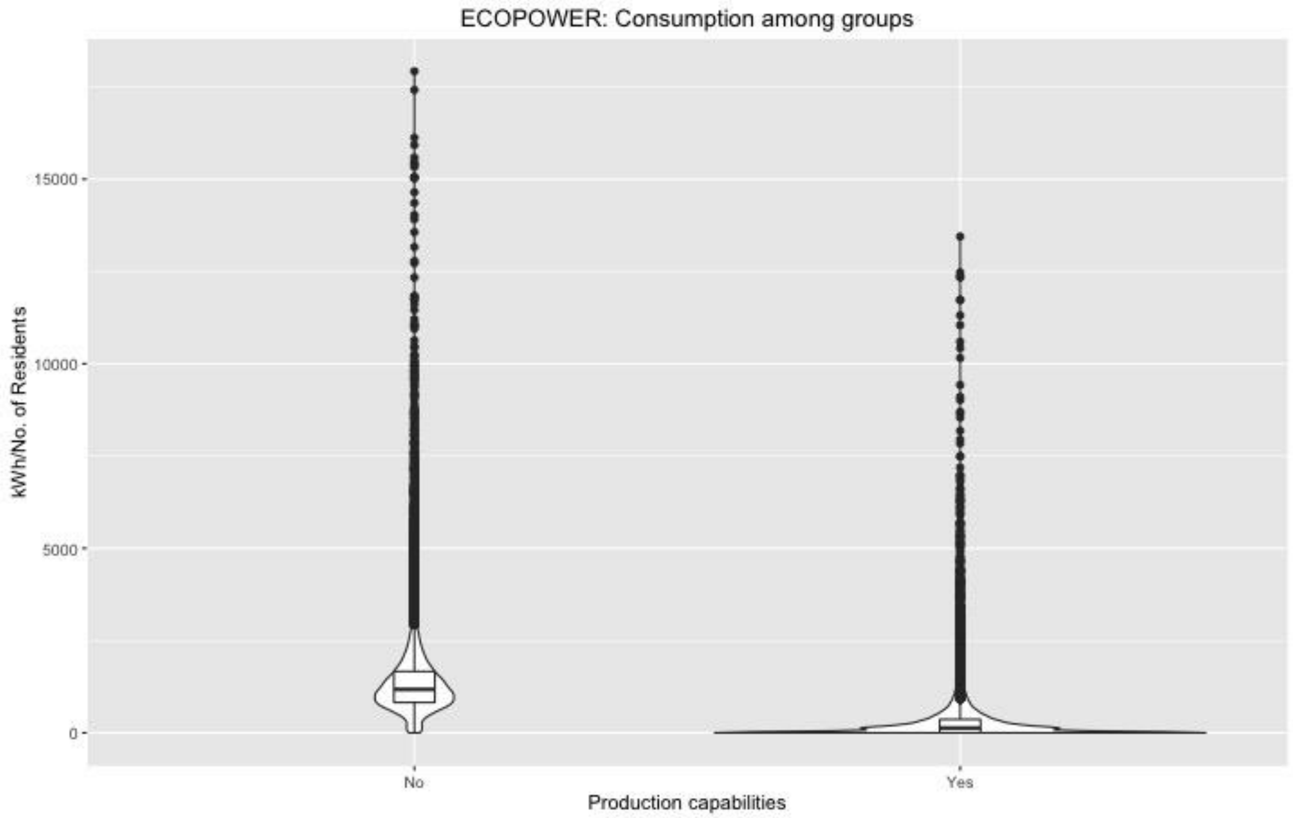

Figure 274 Violin plots of sample distributions by different groups (Production capabilities)

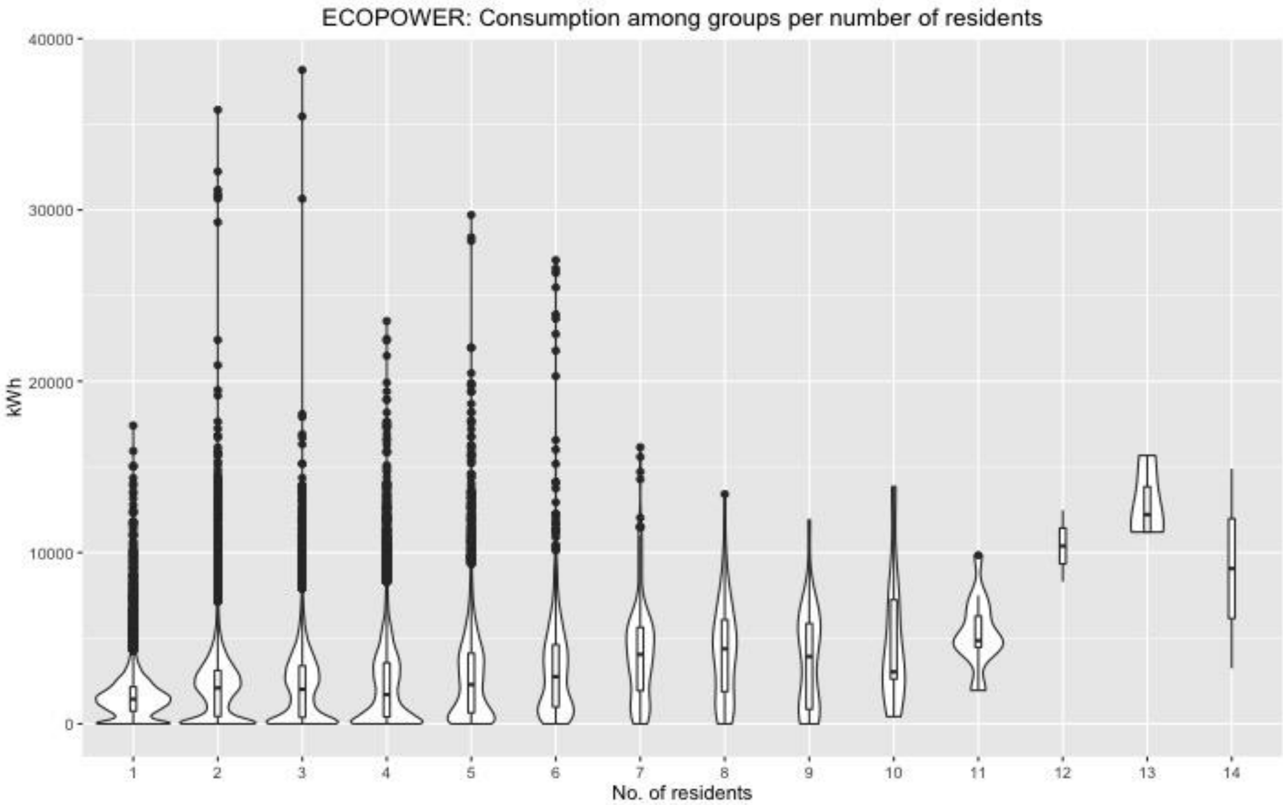

Figure 285 Violin plots of sample distributions by different groups (Number of residents)

Table 25 Average consumption of EBO members

Number of residents	Sample size	Avg. kWh	Sample size	Avg. kWh/m^2
1	19,115	1,602.63	553	13.67
2	35,873	2,114.52	1,593	14.46
3	19,362	2,166.14	817	14.98
4	30,067	2,215.80	1,334	12.99
5	10,581	2,700.50	595	13.50
6	1,989	3,164.53	111	13.81
7	300	4,199.82	19	22.01
8	81	4,225.18	1	22.05
9	32	3,775.15	-	-
10	25	4,819.16	-	-
11	14	5,260.00	-	-
12	2	10,383.00	-	-
13	4	12,824.25	-	-
14	2	9,066.50	-	-
	p-value	< 2.2e-16 ***	< 2.2e-16 ***	< 2.2e-16 ***

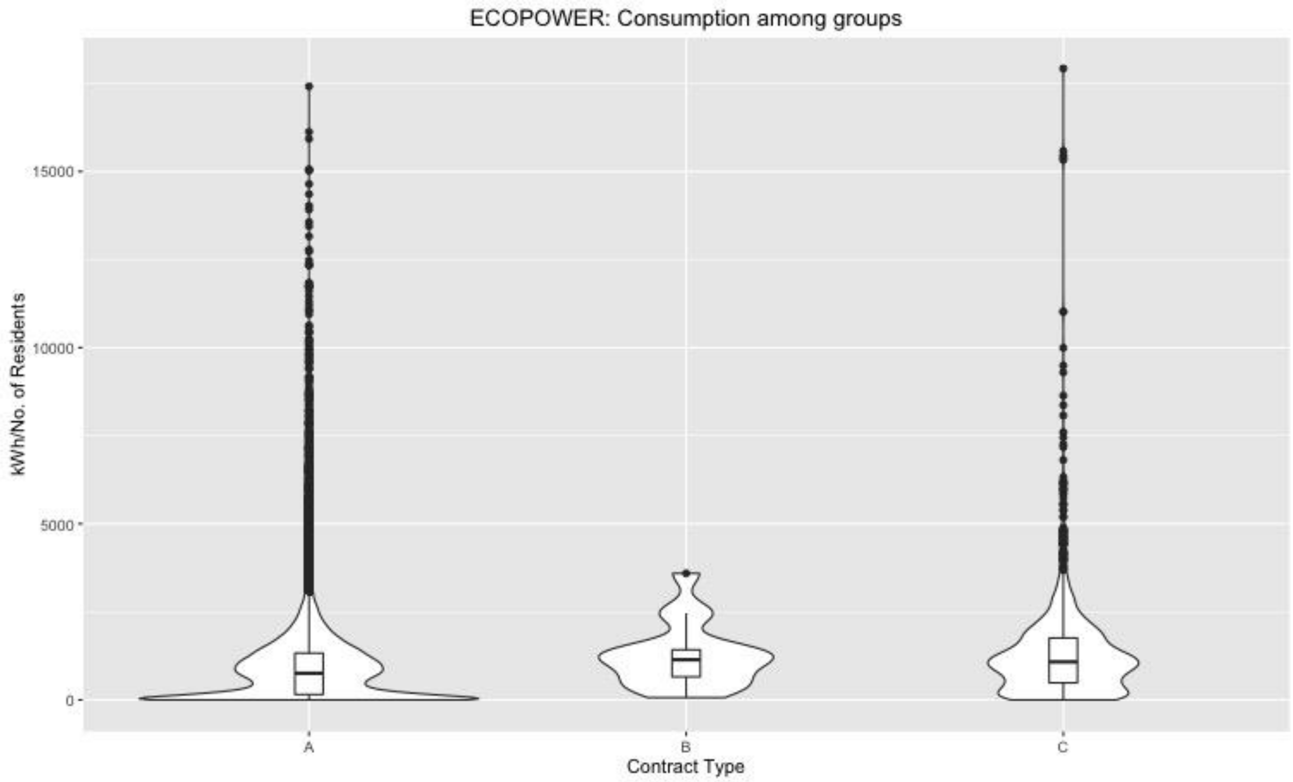

Figure 296 Violin plots of sample distributions by different groups (Contract types)

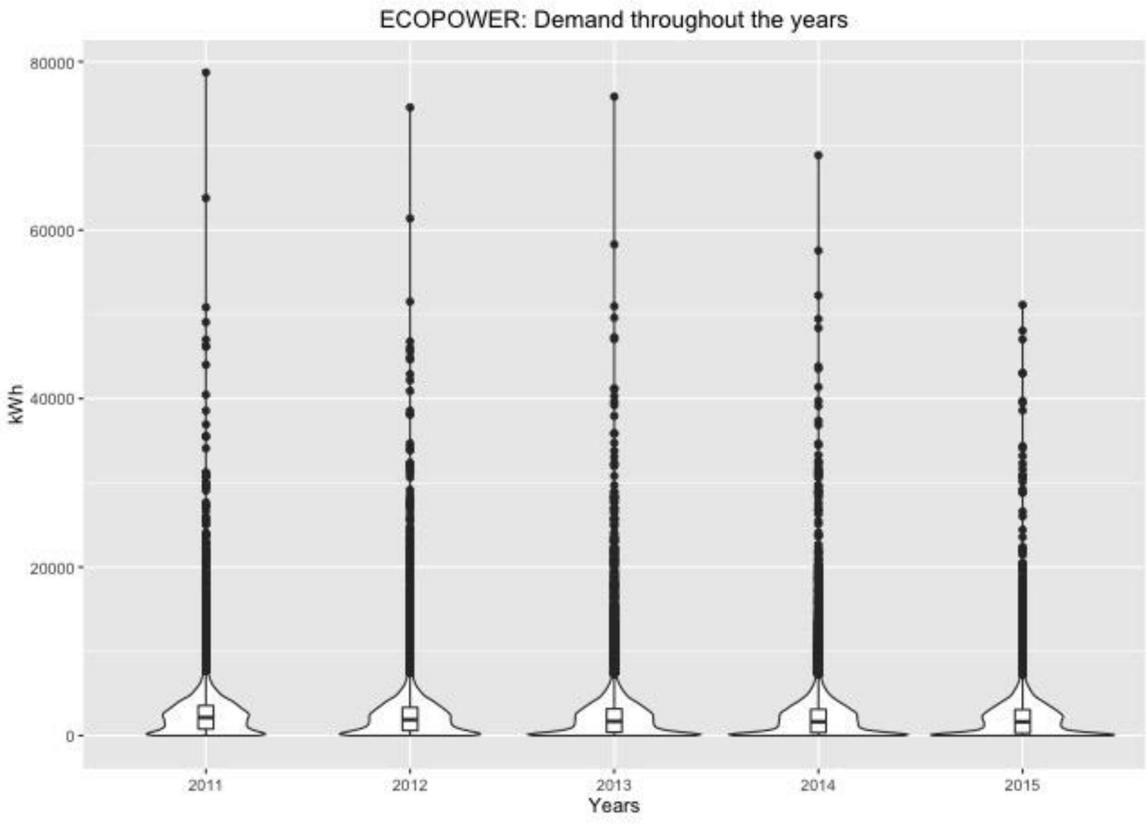

Figure 307 Violin plots of sample distributions by year

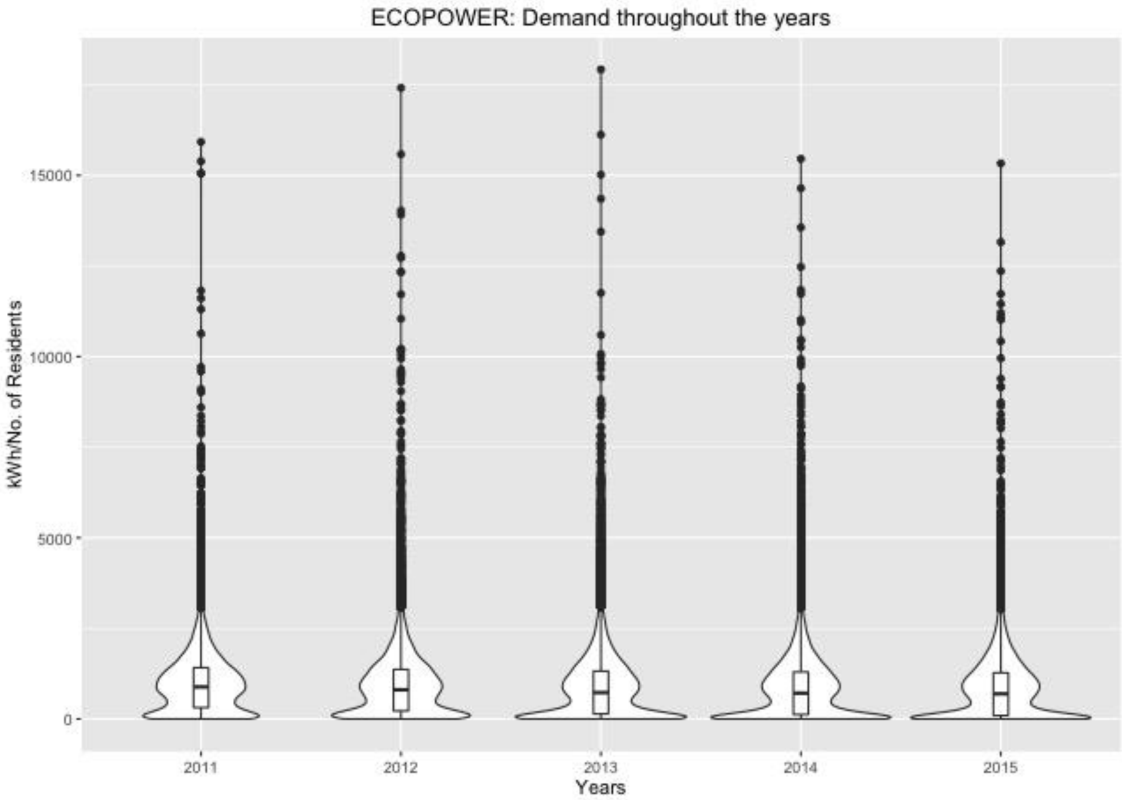

Figure 8 Violin plots of sample distributions by year (kWh/No of Residents)

Table 26 Average consumption of ECOPOWER members

Year	Sample size	Avg. kWh	Sample size	Avg. kWh/No. Of residents	Sample size	Avg. kWh/m^2
2011	28477	2524.33	17829	1012.09	1143	15.13
2012	33197	2341.35	22527	950.82	1280	14.43
2013	33590	2169.34	28276	882.72	1297	13.29
2014	33594	2117.87	30126	863.24	1297	13.12
2015	20600	2078.25	18689	845.07	904	12.87
	p-value	< 2.2e-16 ***		< 2.2e-16 ***		0.0001 ***

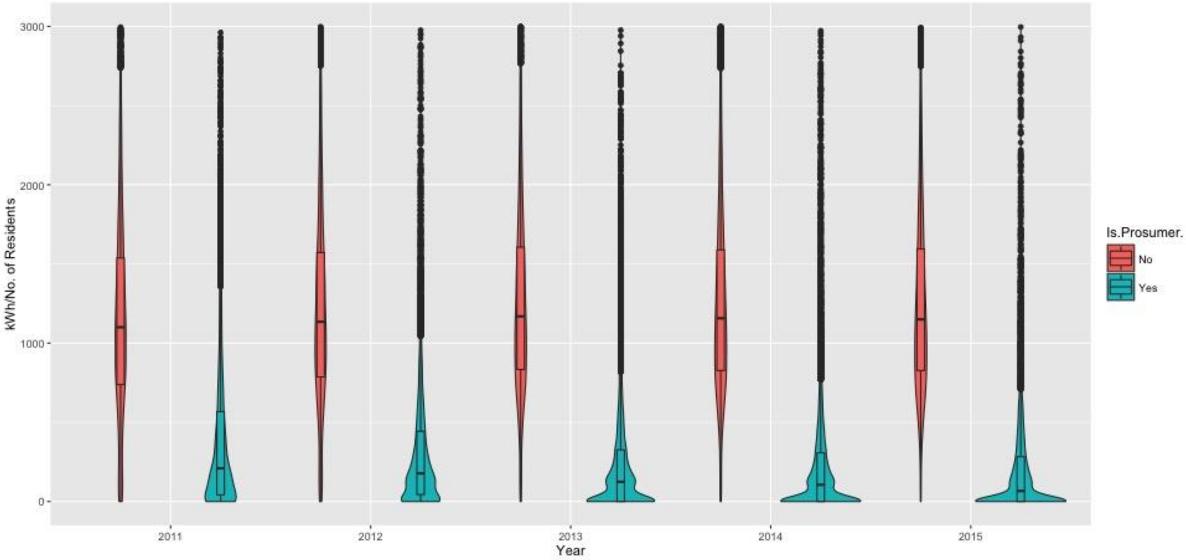

Figure 329 Violin plots of sample distributions without outliers (<3000 kWh/No. of Residents)

Table 27 Average consumption of ECOPOWER members

Member group	Year	Sample size	Avg. kWh/No. of residents	Sample size	Avg. kWh/m^2
Prosumers	2011	5,736	444.89	365	9.25
	2012	8,856	354.63	473	7.73
	2013	12,704	271.18	558	6.05
	2014	13,737	255.47	585	5.85
	2015	8,698	244.28	438	5.64
Not Prosumers	2011	12,093	1,281.13	778	17.89
	2012	13,671	1,337.02	807	18.36
	2013	15,572	1,381.62	739	18.75
	2014	16,389	1,372.66	712	19.09
	2015	9,991	1,368.10	466	19.66
p-value: < 2.2e-16 ***	< 2.2e-16 ***				

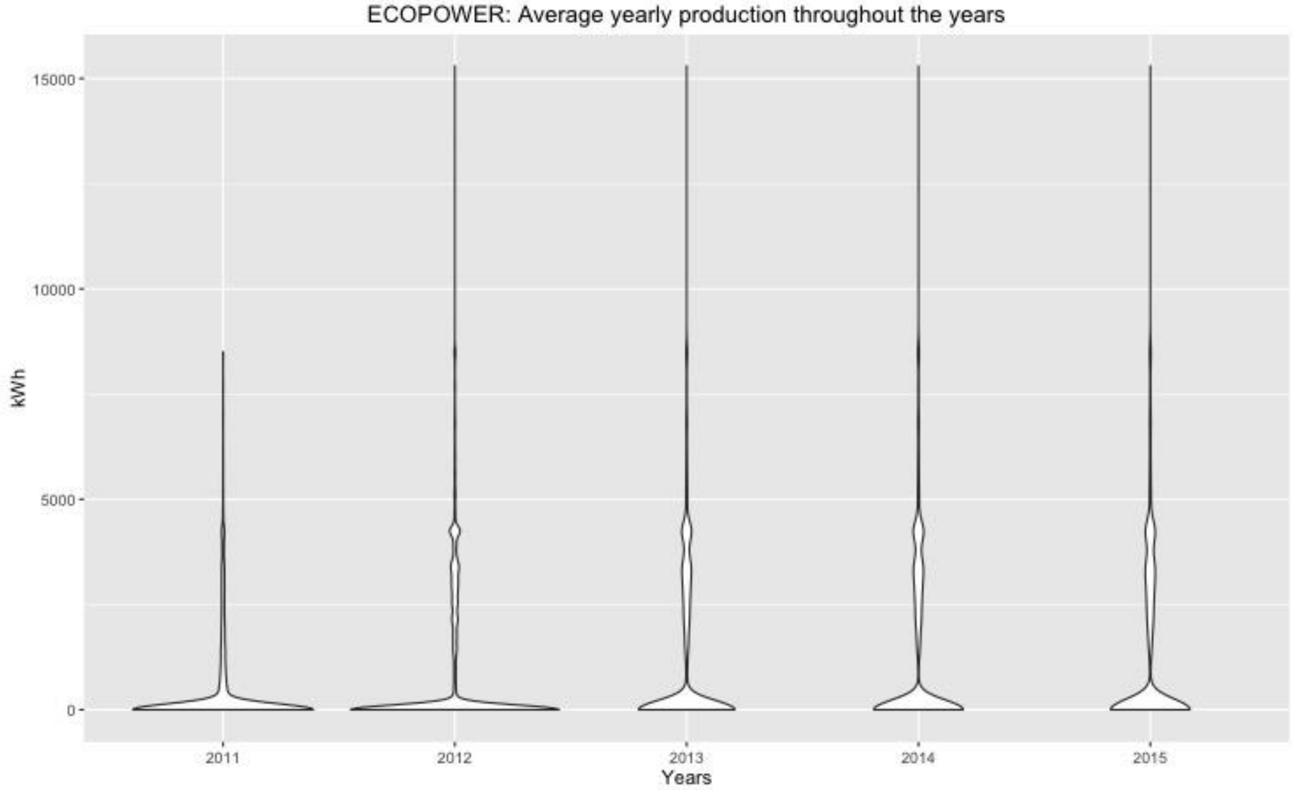

Figure 3310 Violin plots of sample distributions (electricity production measurements)

Table 28 Average yearly production of ECOPOWER prosumers

Year	Sample size	Avg. kWh
2011	25,168	462.97
2012	29,848	893.40
2013	30,239	1,228.90
2014	30,243	1,315.48
2015	18,583	1,354.15
	p-value	< 2.2e-16 ***

Table 29 Average consumption of ECOPOWER members

Contract Type	Sample size	Avg. kWh	Sample size	Avg. kWh/No. Of residents	Sample size	Avg. kWh/m^2
A	141,718	2,108.86	115,546	897.34	5,787	13.77
B	5,558	5,699.75	16	1,259.96	57	12.60
C	2,182	2,702.34	1,885	1,336.25	77	16.20
	p-value	< 2.2e-16 ***		< 2.2e-16 ***		< 2.2e-16 ***

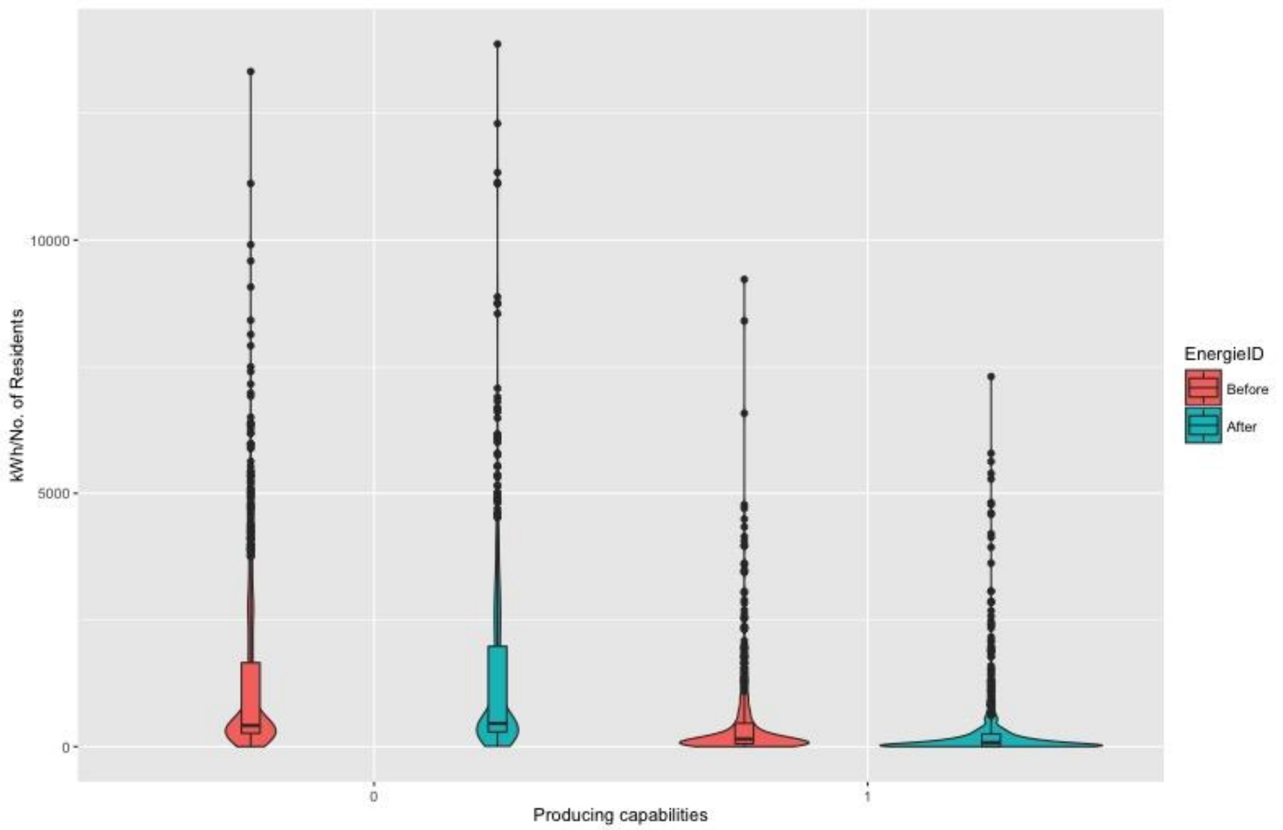

Figure 3411 Violin plots of sample distributions before and after EnergieID, by customer group

Table 30 Average consumption of ECOPOWER members per producing capabilities group, before, and after subscribing to EnergieID.

Producing capabilities	Sample size	EnergieID	Avg. kWh/No. of residents	Reduction	Reduction %
Yes	789	Before	502.74	183.69	36.53%
		After	319.05		
No	1,218	Before	1,191.84	-108.45	-9.09%
		After	1,300.29		
p-value: < 2.2e-16 ***		0.018*			

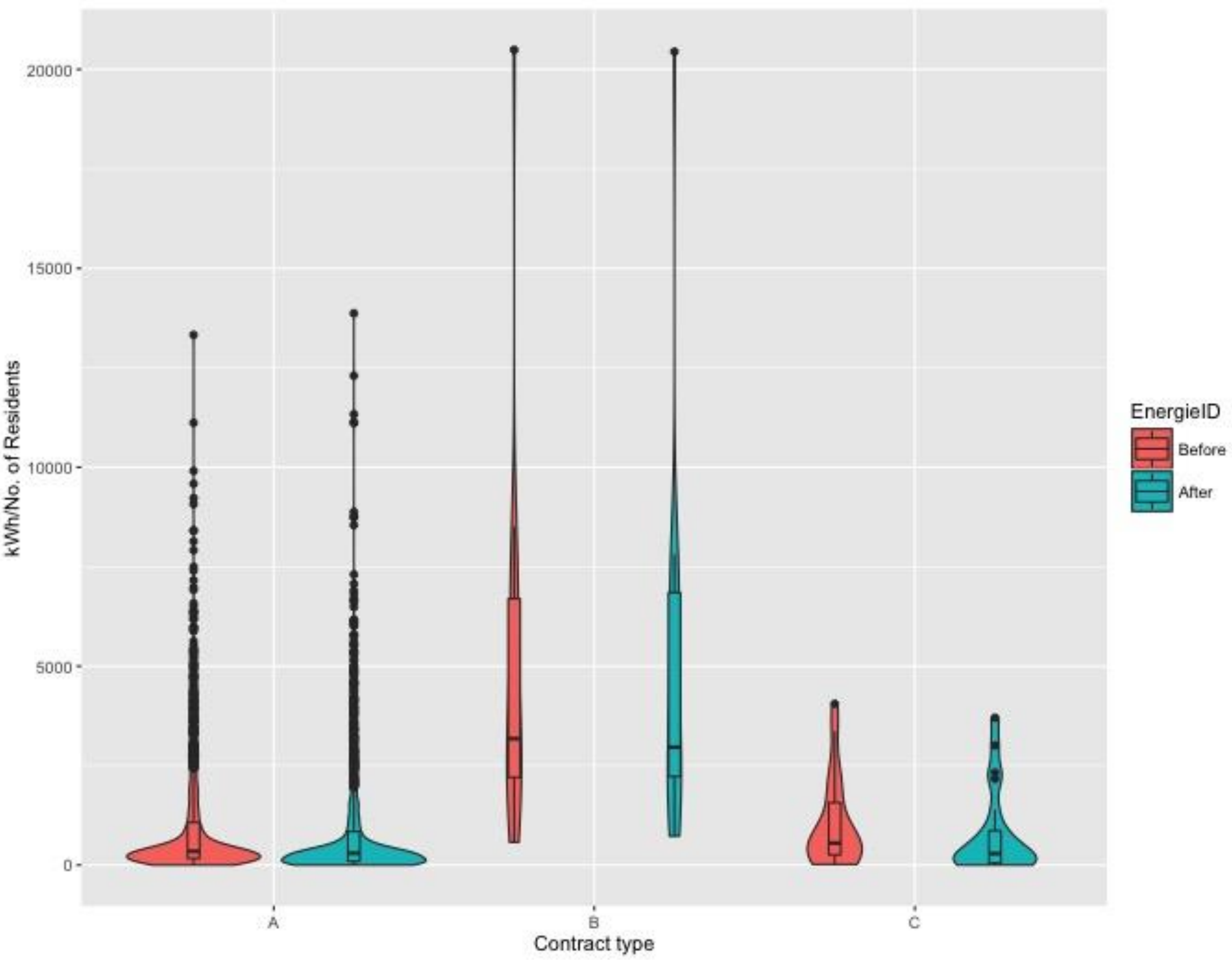

Figure 3512 Violin plots of sample distributions before and after EnergieID, by contract type

Table 31 Average consumption of ECOPOWER members per contract type group, before, and after subscribing to EnergieID.

Contract type	Sample size	EnergieID	Avg. kWh/No. of residents	Reduction	Reduction %
A	1764	Before	978.55	117.15	11.97%
		After	861.40		
B	20	Before	4,725.22	-7	-0.14%
		After	4,732.22		
C	21	Before	1,014.55	213.03	20.99%
		After	801.52		
p-value: < 2e-16 ***		0.019*			

EE Intervention Application Impacts (Leaflets)

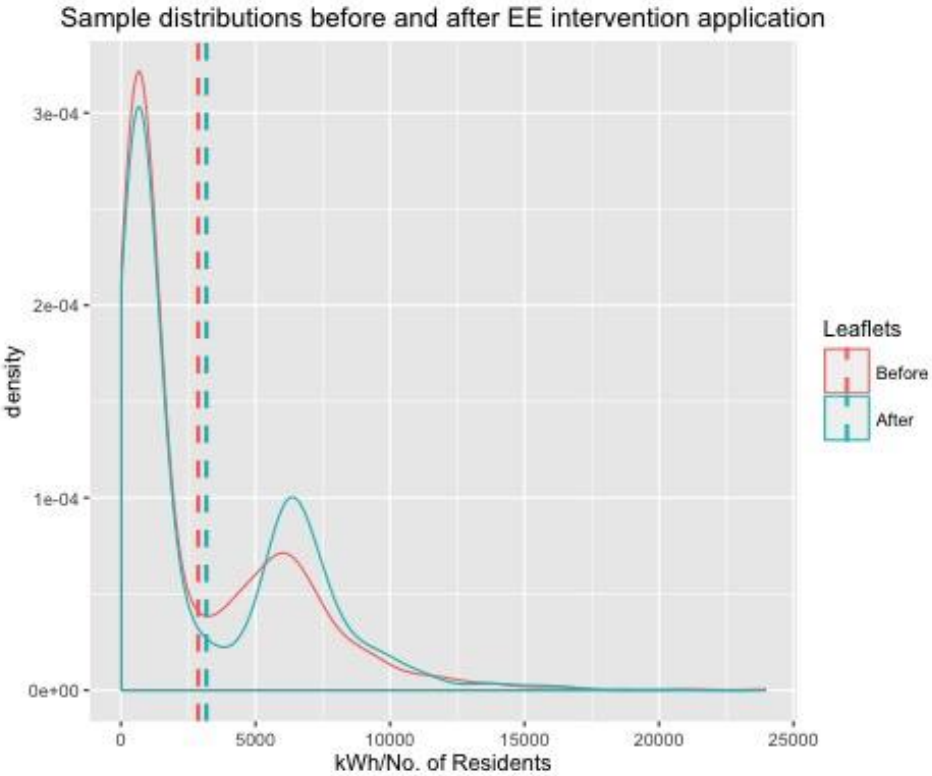

Figure 36 Kernel Density estimates of electricity consumption in kWh/No. of Residents samples for all ECOPOWER members, before, and after receiving EE leaflets. Dashed horizontal lines represent the average of each sample group.

Table 32 Average consumption values, reductions, and significance tests, before, and after receiving EE leaflets.

		Electricity Consumption			
Leaflets	Sample size	Avg. yearly kWh	Avg. yearly kWh/No. of Residents	Sample size	Avg. yearly kWh/m^2
Before reception	1243	6,800.38	2,872.87	43	33.83
After reception	1243	7,160.91	3,178.94	43	37.68
	Reduction	-360.53	-306.07		-3.85
	Reduction (%)	-5.30	-10.65		-11.38
	Estimated CO2 reductions / typical customer (kg)	-91.43			
	p-value	0.0007 ***	0.022 *		0.252
	Kendall's tau	0.434	0.729		0.645

In the analysis of the leaflets EE intervention measure we observed that it actually had a negative impact on the indices of interest (Figure 36 and Table 32). In Figure 36 we observe an increase especially in the density of kWh/No. of Residents with value about 6,000. Our sample size for yearly kWh and kWh/No. of Residents was 1,243, and only 43 for kWh/m^2 consumption. The reduction caused by the application of leaflets was negative valued for all three indices.

The p-values related to the kWh (0.0007) and kWh/No.of.Residents (0.022) indices imply that the adoption of leaflets had a strong effect on them. However, this does not hold in the case of kWh/m^2 index, where the corresponding p-value (0.252) is much greater than 0.05. The Kendall's tau coefficient related to kWh/m^2 (0.645) contradictory indicates that the application of leaflets must have had an impact on kWh/m^2. This contrast is caused by the very small sample size (43), and thus we are unable to tell whether leaflets had actually had a strong impact on the kWh/m^2 index.

As results in Appendix – Ecopower (Figures 36, 37) indicate further, the EE leaflets intervention is not effective on any customer group type.

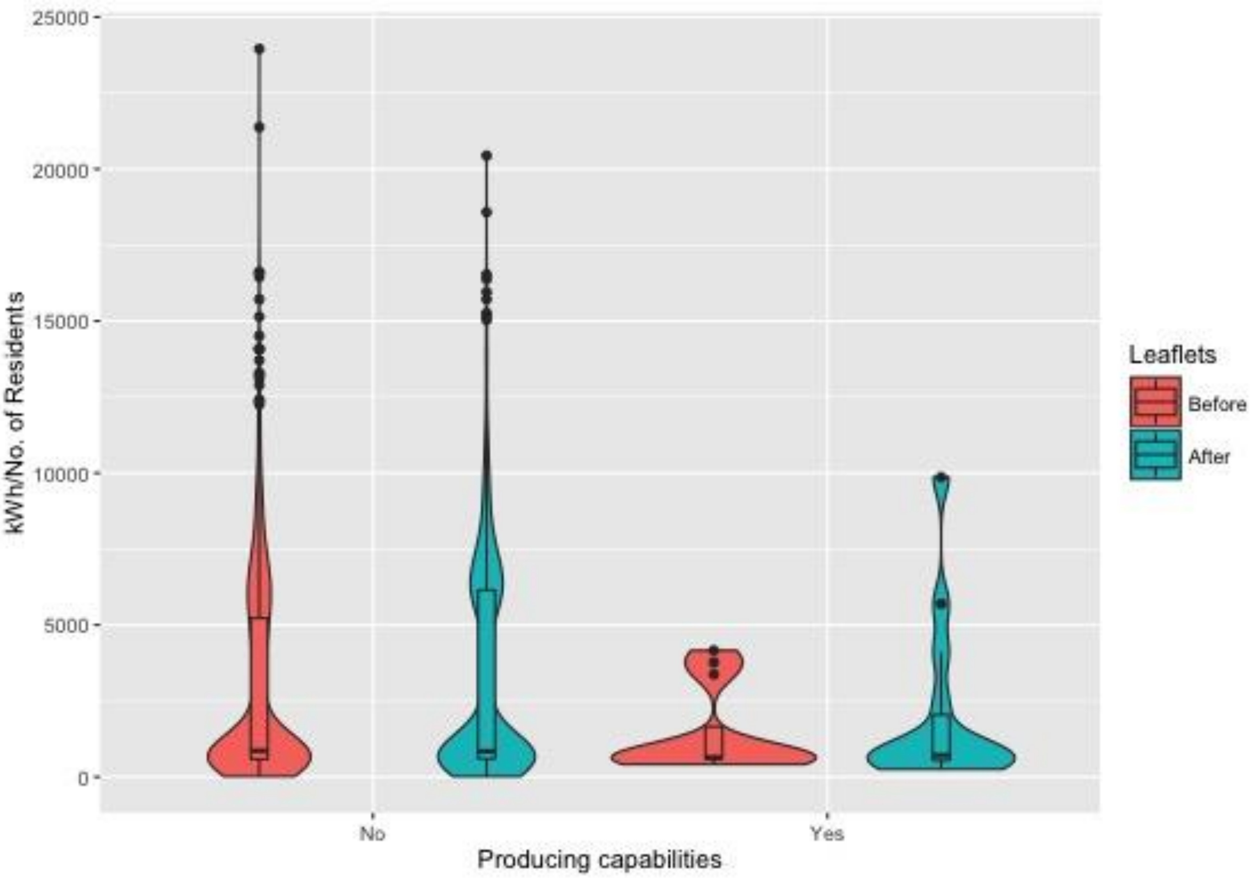

Figure 3713 Violin plots of sample distributions before and after EE leaflets, by customer group

Table 33 Average consumption of ECOPOWER members per producing capabilities group, before, and after receiving EE leaflets.

Producing capabilities	Sample size	Leaflets	Avg. kWh/No. of residents	Reduction	Reduction %
Yes	14	Before	2,886.90	-305.22	-10.57%
		After	3,192.12		
No	1,231	Before	1,433.94	-587.26	-40.95%
		After	2,021.20		
p-value: 0.048*		0.021*			

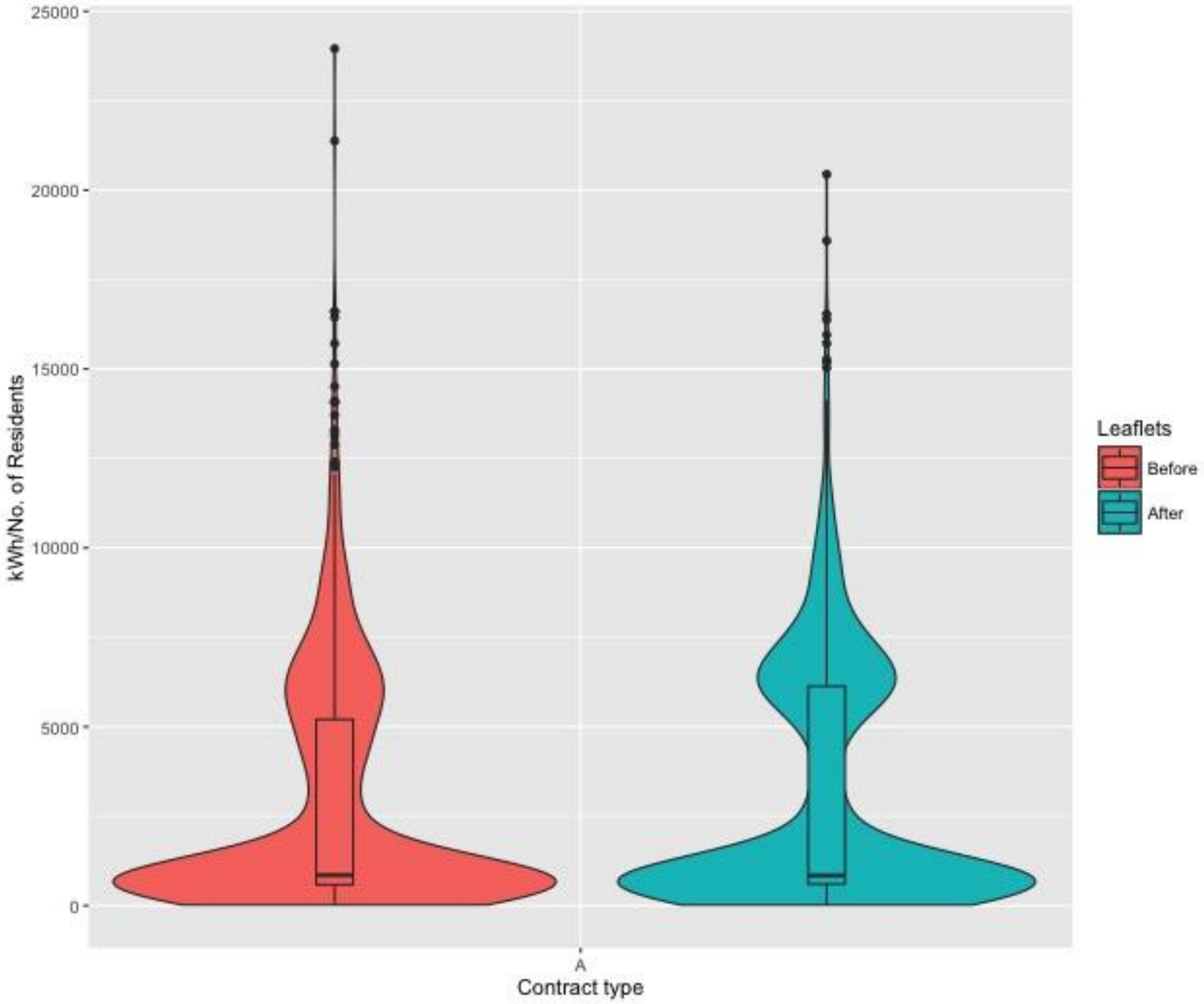

Figure 38 Violin plots of sample distributions before and after EE leaflets, (Contract type A)

Table 34 Average consumption of ECOPOWER members per contract type group, before, and after receiving EE leaflets.

Contract type	Sample size	Leaflets	Avg. kWh/No. of residents	Reduction	Reduction %
A	1242	Before	2,872.75	-306.25	-10.66%
		After	3,179.01		
	p-value	0.022 *			

ENERCOOP

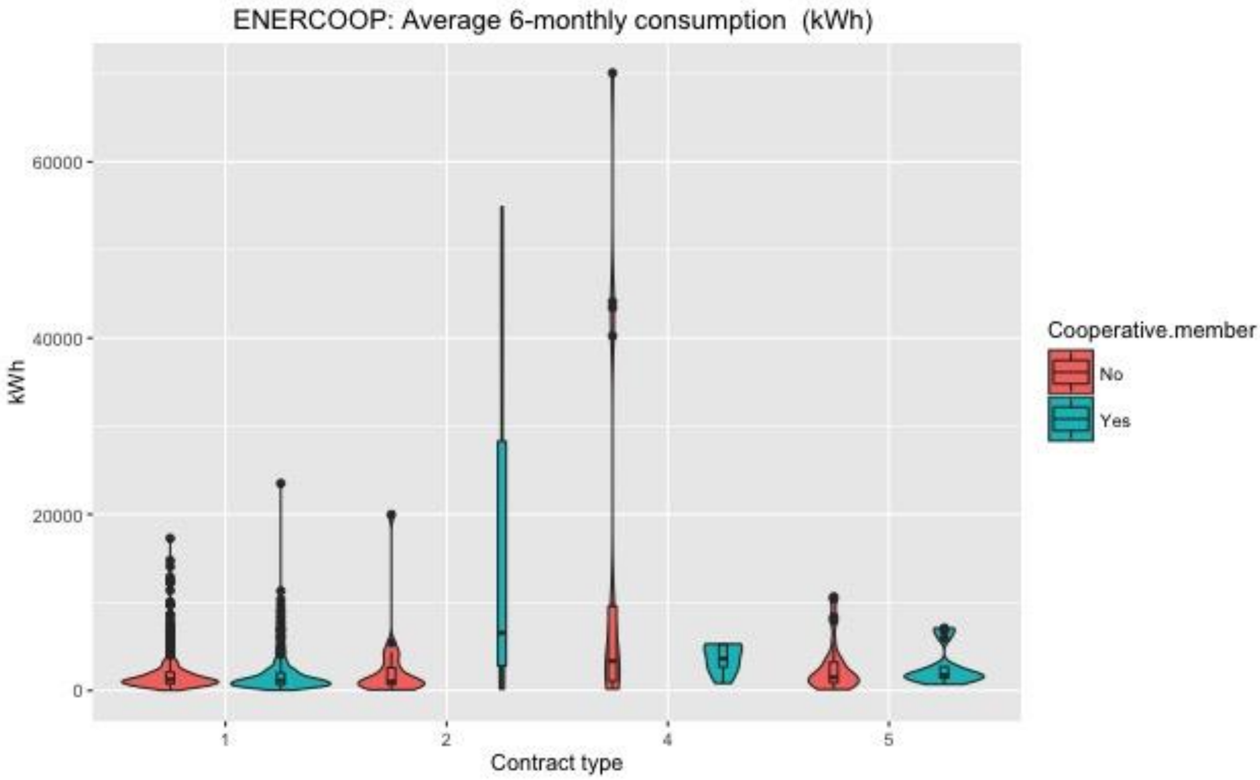

Figure 3914 Violin plots of sample distributions (Contract types – Cooperative membership)

Table 35 Average consumption of ENERCOOP members

Contract type	Is cooperative member	Sample size	Avg. 6-monthly kWh	Avg. 6-monthly kWh/DD
1	No	757	1,839.27	24.99
	Yes	498	1,659.21	19.38
2	No	25	2,393.61	47.75
	Yes	14	1,6567.48	292.68
4	No	18	1,3442.83	160.14
	Yes	8	3,582.58	93.61
5	No	31	2,683.30	50.56
	Yes	15	2,657.54	30.78
p-value: <2e-16 ***	0.780			

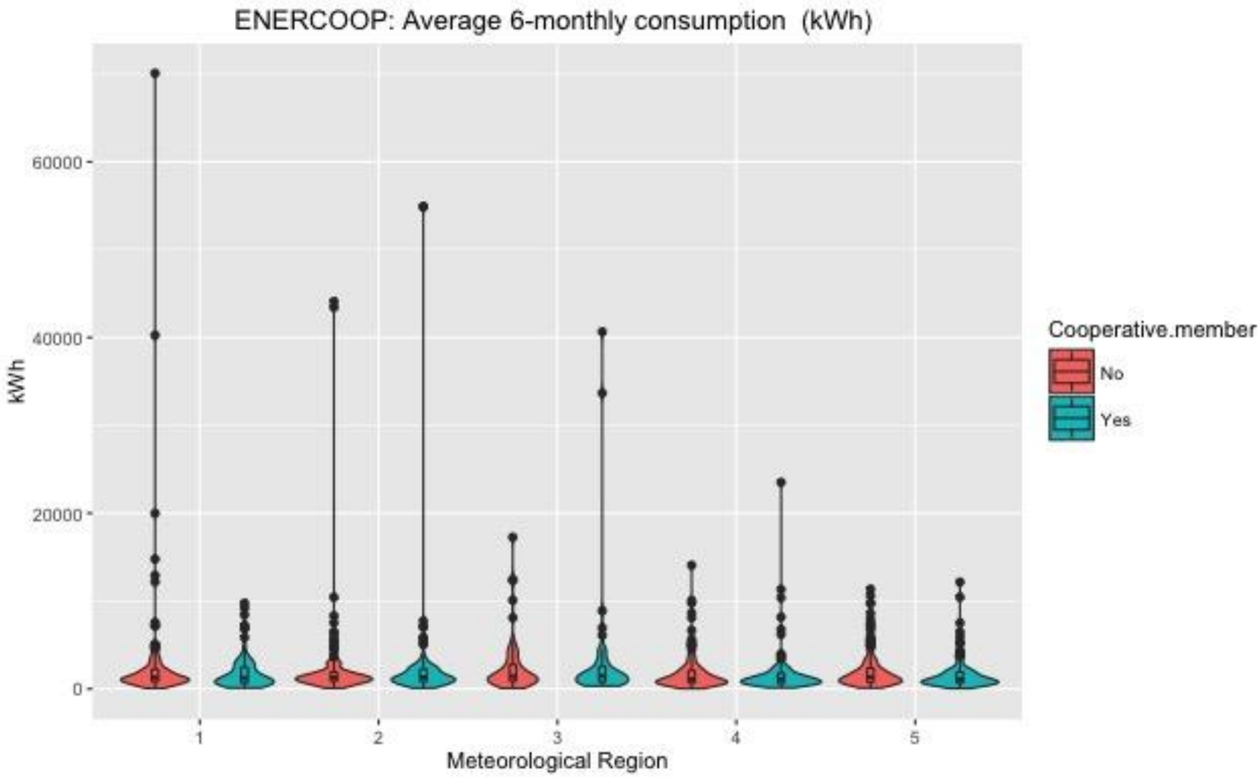

Figure 4015 Violin plots of sample distributions (Meteorological regions – Cooperative membership)

Table 36 Average consumption of ENERCOOP members

Meteorological region	Is cooperative member	Sample size	Avg. 6-monthly kWh	Avg. 6-monthly kWh/DD
1	No	176	2,583.63	21.71
	Yes	137	1784.42	13.67
2	No	162	2,205.66	25.19
	Yes	117	2,613.36	30.20
3	No	72	2,478.50	15.21
	Yes	55	3,225.65	21.89
4	No	157	1,780.48	9.63
	Yes	93	1,889.07	10.05
5	No	264	1,921.58	53.23
	Yes	133	1,679.92	55.74
p-value: 0.095(kWh) . 3.809e-11 (kWh/DD)***	0.730 (kWh) 0.907 (kWh/DD)			

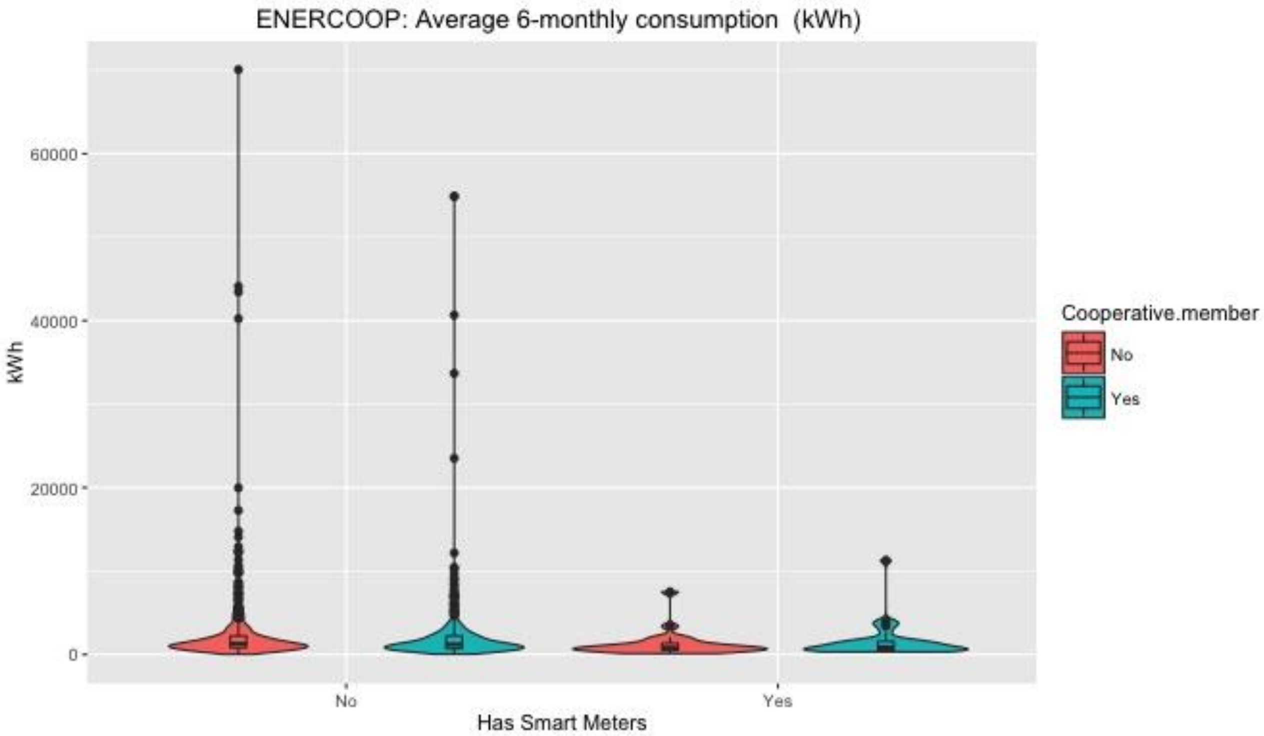

Figure 4116 Violin plots of sample distributions (Smart meters – Cooperative membership)

Table 37 Average consumption of ENERCOOP members

Has Smart Meter	Is cooperative member	Sample size	Avg. 6-monthly kWh	Avg. 6-monthly kWh/DD
No	No	808	2,163.44	29.91
	Yes	504	2,139.68	28.69
Yes	No	23	1,272.24	16.96
	Yes	31	1,559.89	16.04
p-value: 0.212	0.961			

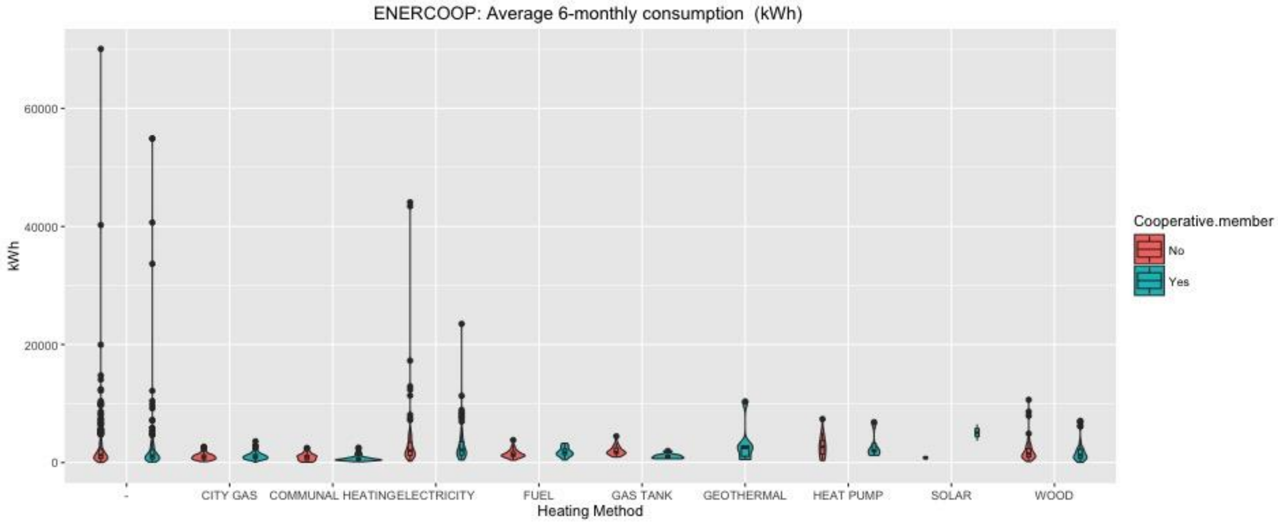

Figure 42 Violin plots of sample distributions (Heating method – Cooperative membership)

Table 38 Average consumption of ENERCOOP members

Heating Method	Cooperative member	Sample Size	Avg. 6-monthly kWh	Avg. 6-monthly kWh/DD
-	No	348	2,363.04	29.00
	Yes	219	2,489.52	37.02
City Gas	No	128	1,016.36	16.07
	Yes	96	1,120.76	13.05
Communal Heating	No	53	951.57	12.00
	Yes	37	754.54	9.85
Electricity	No	136	3,331.78	46.15
	Yes	87	2,985.68	33.58
Fuel	No	35	1,470.73	21.51
	Yes	15	1,803.34	19.80
Gas Tank	No	16	2,047.89	31.61
	Yes	8	1,084.22	16.10
Geothermal	No	-	-	-
	Yes	6	3,235.08	21.05
Heat Pump	No	21	2,773.44	39.26
	Yes	4	3,027.27	23.55
Solar	No	2	821.31	4.53
	Yes	2	5,079.25	103.28
Wood	No	92	1,926.15	37.05
	Yes	61	1,784.94	23.94
p-value: 1.357e-06 ***	0.982			

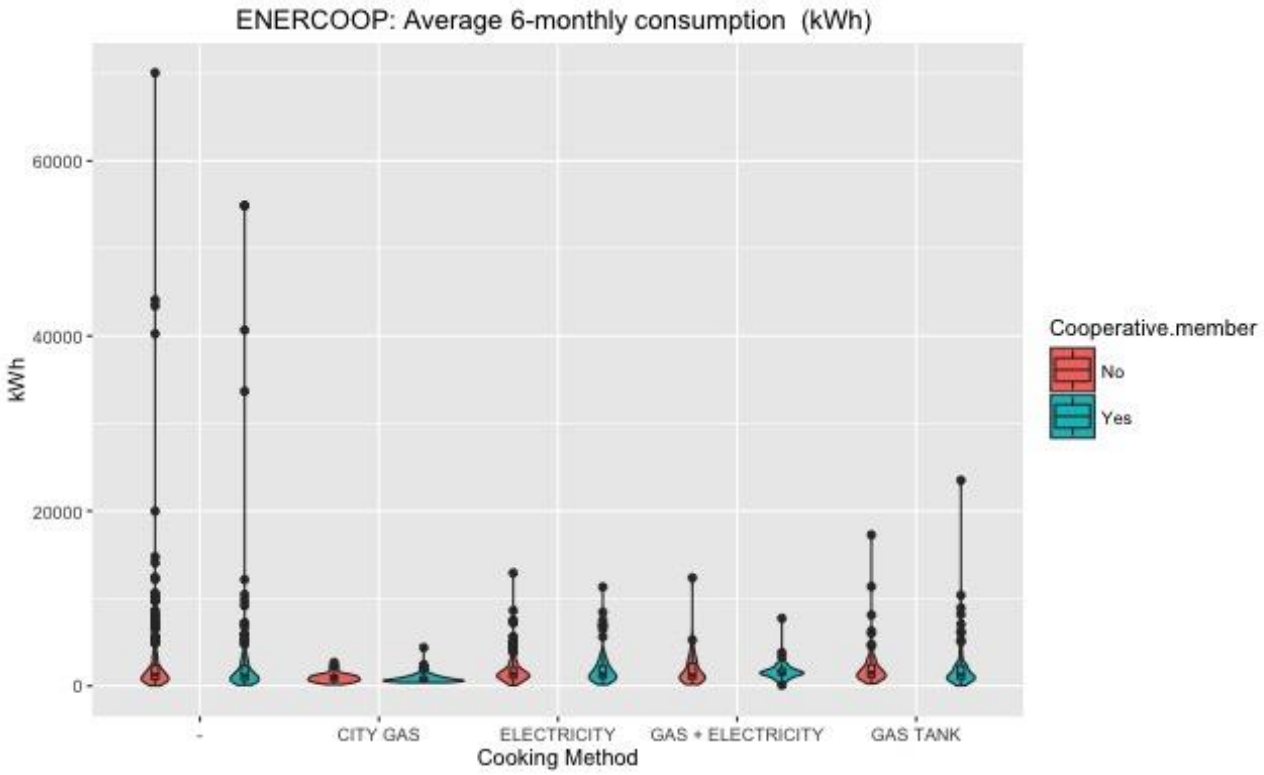

Figure 4317 Violin plots of sample distributions (Cooking method – Cooperative membership)

Table 39 Average consumption of ENERCOOP members

Cooking Method	Cooperative member	Sample Size	Avg. 6-monthly kWh	Avg. 6-monthly kWh/DD
-	No	369	2,617.18	34.47
	Yes	229	2,521.33	37.98
City Gas	No	81	957.89	15.24
	Yes	67	934.59	12.38
Electricity	No	200	1,844.78	25.73
	Yes	132	1,936.02	21.38
Gas+Electricity	No	49	1,929.75	21.18
	Yes	27	1,853.58	22.41
Gas Tank	No	132	2,049.07	33.52
	Yes	80	2,264.37	25.06
p-value: 0.0003697 ***	0.818			

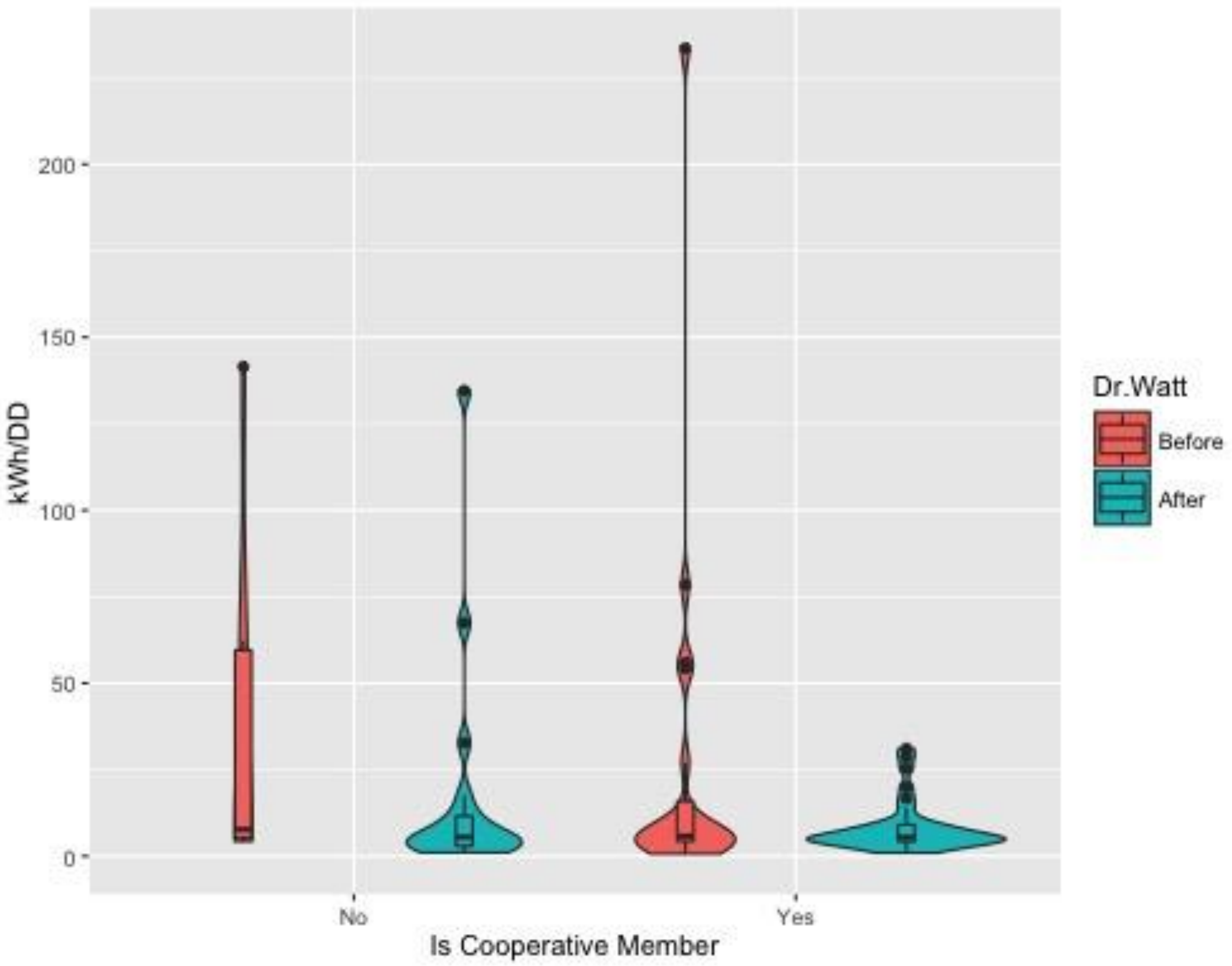

Figure 4418 Violin plots of sample distributions, before, and after Dr. Watt, per customer membership group

Table 40 Average consumption of ENERCOOP members per producing capabilities group, before, and after subscribing to Dr. Watt.

Is cooperative member	Dr. Watt	Sample Size	Avg. kWh/DD	Reduction	Reduction %
No	Before	8	36.56	17.91	48.98%
	After	17	18.65		
Yes	Before	20	26.29	18.03	68.58%
	After	36	8.26		
p-value: 0.213	p-value: 0.030*				

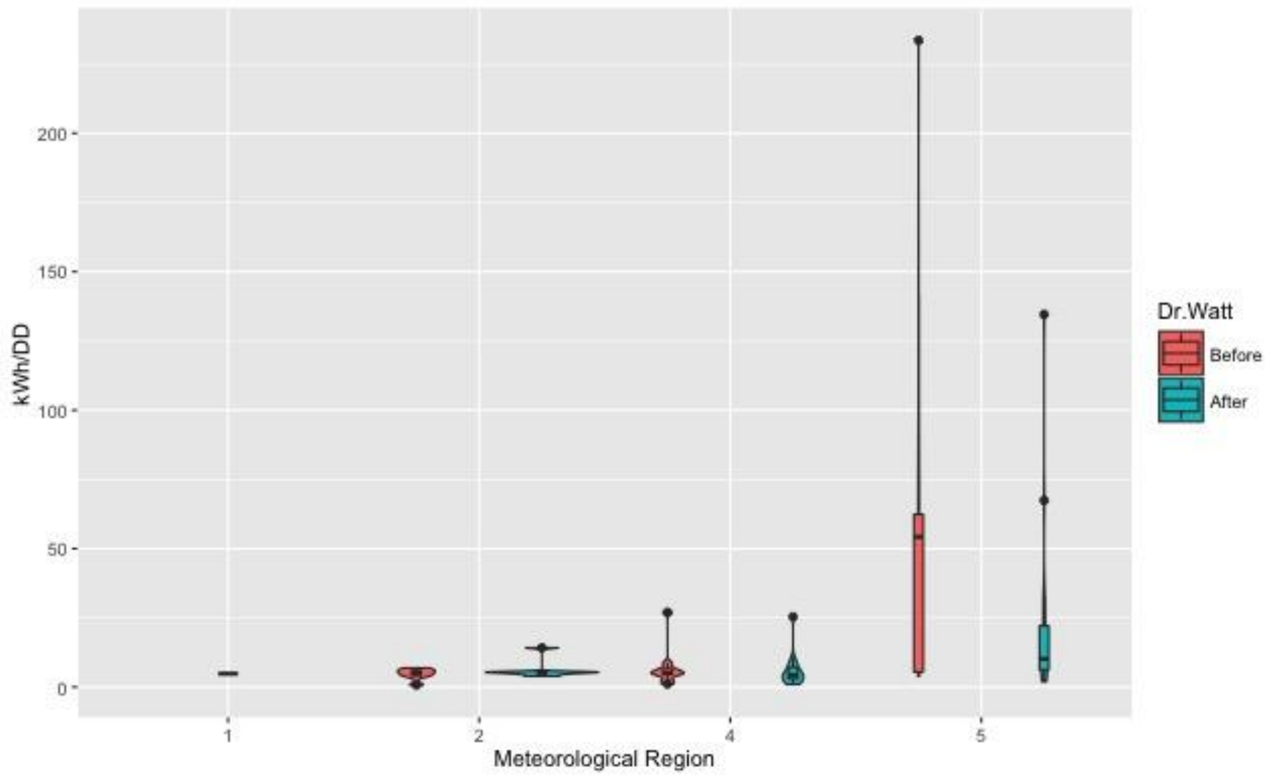

Figure 45 Violin plots of sample distributions, before, and after Dr. Watt, per meteorological region

Table 41 Average consumption of ENERCOOP members per producing capabilities group, before, and after subscribing to Dr. Watt.

Meteorological Region	Dr. Watt	Sample Size	Avg. kWh/DD	Reduction	Reduction %
1	Before	-	-	-	-
	After	1	4.81		
2	Before	6	4.64	-1.65	-35.56%
	After	7	6.29		
4	Before	9	7.34	1.88	25.61%
	After	25	5.46		
5	Before	13	55.72	34.26	61.48%
	After	20	21.46		
p-value: 0.021*	p-value: 0.030*				

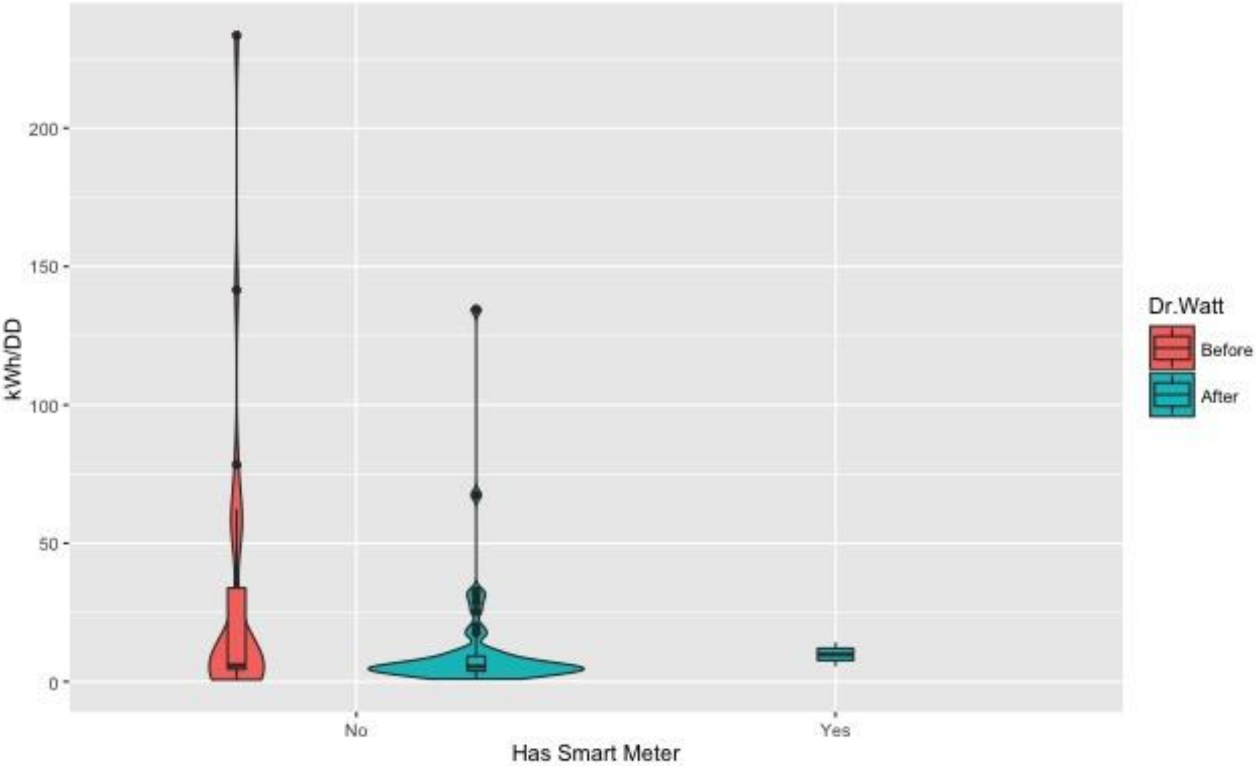

Figure 4619 Violin plots of sample distributions, before, and after Dr. Watt, for customers with and without smart meters

Table 42 Average consumption of ENERCOOP members per producing capabilities group, before, and after subscribing to Dr. Watt.

Has Smart Meter	Dr. Watt	Sample Size	Avg. kWh/DD	Reduction	Reduction %
No	Before	28	36.56	24.9	68.10%
	After	51	11.66		
Yes	Before	-	-	-	-
	After	2	9.84		
p-value: 0.941	p-value: 0.032*				

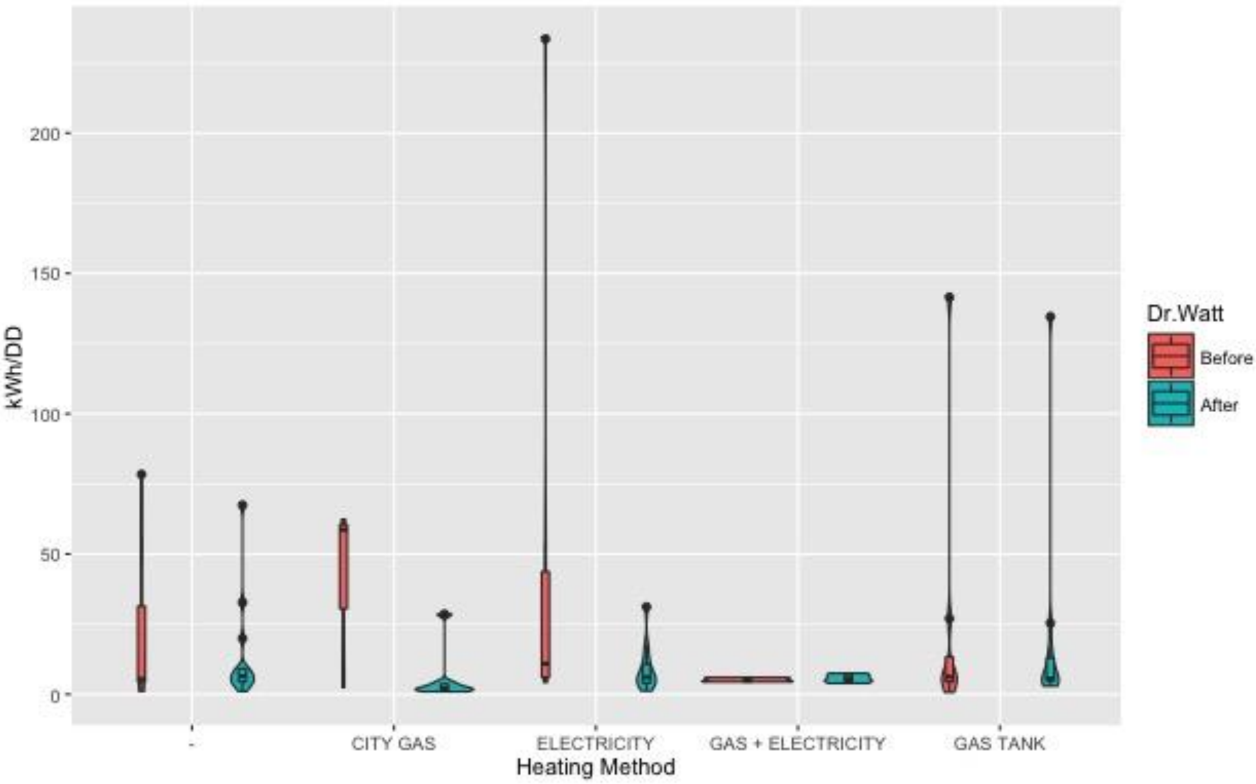

Figure 47 20 Violin plots of sample distributions, before, and after Dr. Watt, per cooking method group

Table 43 Average consumption of ENERCOOP members per producing capabilities group, before, and after subscribing to Dr. Watt.

Cooking Method	Dr. Watt	Sample Size	Avg. kWh/DD	Reduction	Reduction %
-	Before	7	22.38	9.91	44.28%
	After	15	12.47		
City Gas	Before	3	41.13	35.12	85.38%
	After	7	6.01		
Electricity	Before	6	53.10	44.21	83.25%
	After	14	8.89		
Gas+Electricity	Before	4	5.15	-0.56	-10.87%
	After	5	5.71		
Gas Tank	Before	8	24.88	5.51	22.14%
	After	12	19.37		
p-value: 0.716	p-value: 0.033*				

SOMENERGIA

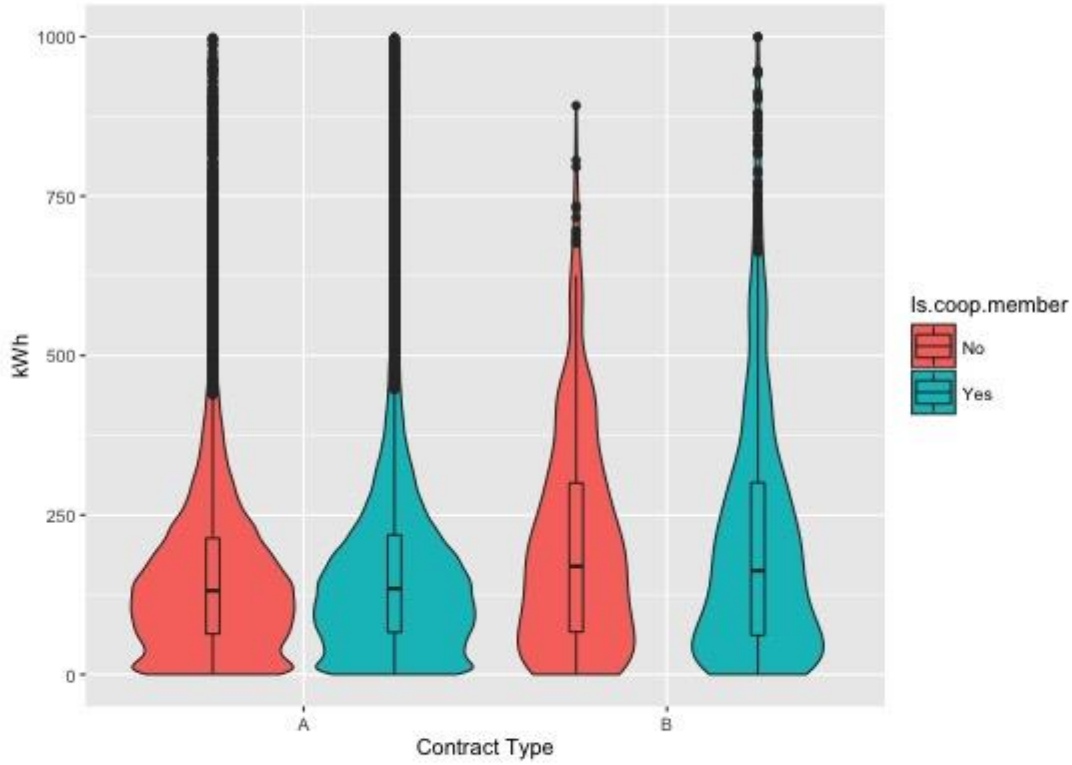

Figure 4821 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 44 Average consumption of SOMENERGIA members

Contract type	Is cooperative member	Sample size	Avg. monthly kWh	Avg. monthly kWh/DD
A	No	32343	177.82	1.77
	Yes	71896	184.80	1.91
B	No	516	224.30	2.58
	Yes	1293	262.89	2.94
p-value: < 2.2e-16 ***	1.909e-07 ***			

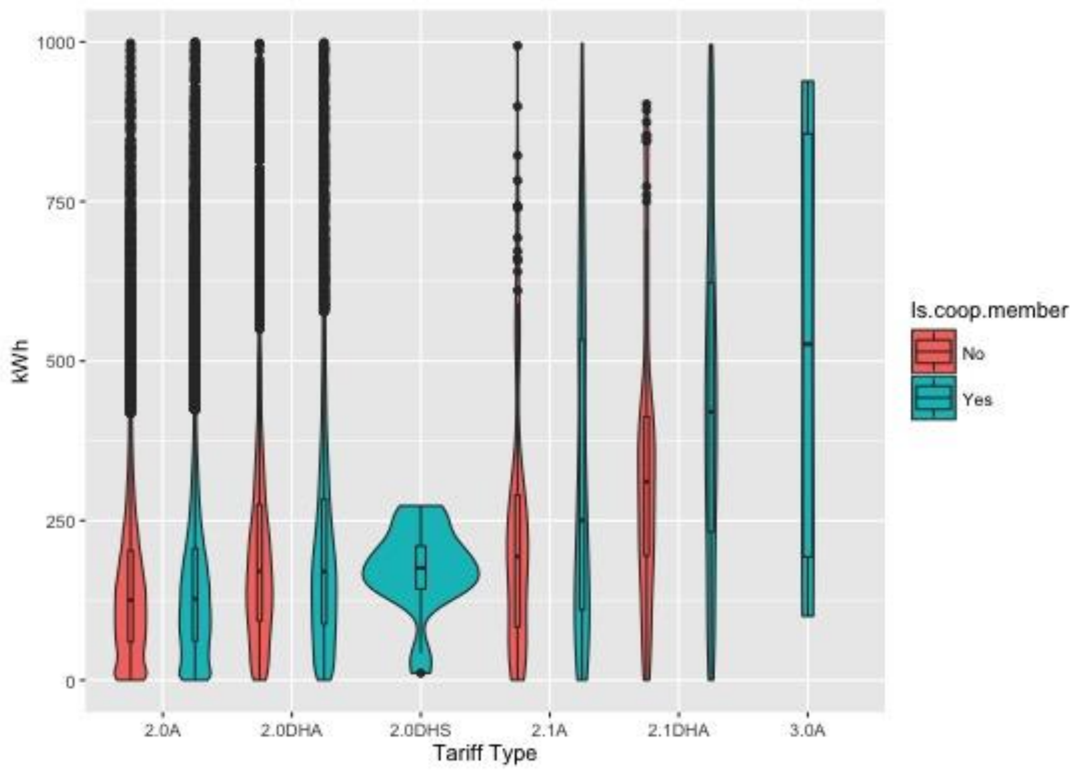

Figure 49 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 45 Average consumption of SOMENERGIA members

Tariff type	Is cooperative member	Sample size	Avg. monthly kWh	Avg. monthly kWh/DD
2.0A	No	27854	161.27	1.65
	Yes	59398	164.90	1.76
2.0DHA	No	4686	266.14	2.36
	Yes	12822	247.86	2.40
2.0DHS	No	-	-	-
	Yes	20	174.18	3.29
2.1A	No	191	285.48	5.27
	Yes	358	478.26	3.85
2.1DHA	No	128	570.83	4.18
	Yes	581	804.98	6.60
3.0A	No	-	-	-
	Yes	10	1060.95	7.60
p-value: < 2e-16 ***	0.080 .			

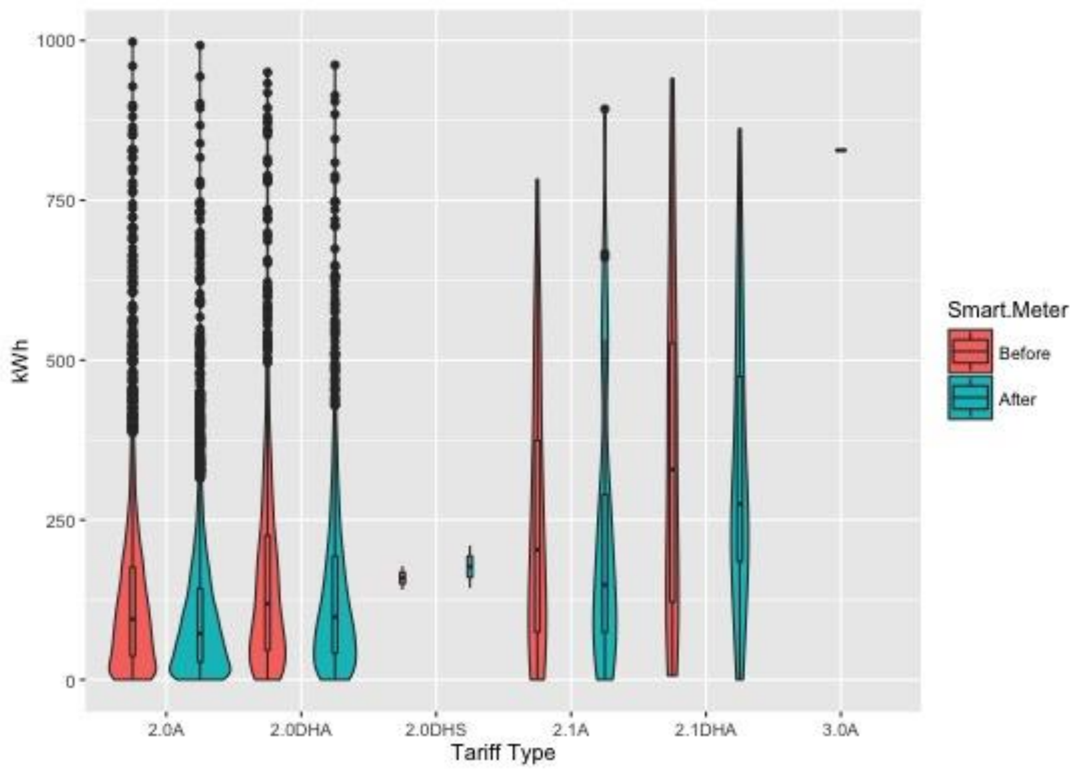

Figure 5022 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 46 Average consumption (kWh/DD) of SOMENERGIA members per tariff type group, before, and after installing Smart Meters.

Tariff type	Sample size	Smart Meter	Avg. kWh/DD	Reduction	Reduction %
2.0A	4919	Before	1.46	0.61	41.78%
		After	0.85		
2.0DHA	1009	Before	2.30	1.31	56.95%
		After	0.99		
2.0DHS	2	Before	1.07	0.43	40.18%
		After	0.64		
2.1A	38	Before	2.37	0.24	10.12%
		After	2.13		
2.1DHA	50	Before	11.63	9.08	78.07%
		After	2.55		
3.0A	1	Before	3.08	-4.89	-158.76%
		After	7.97		
p-value: 0.003 **		7.305e-14 ***			

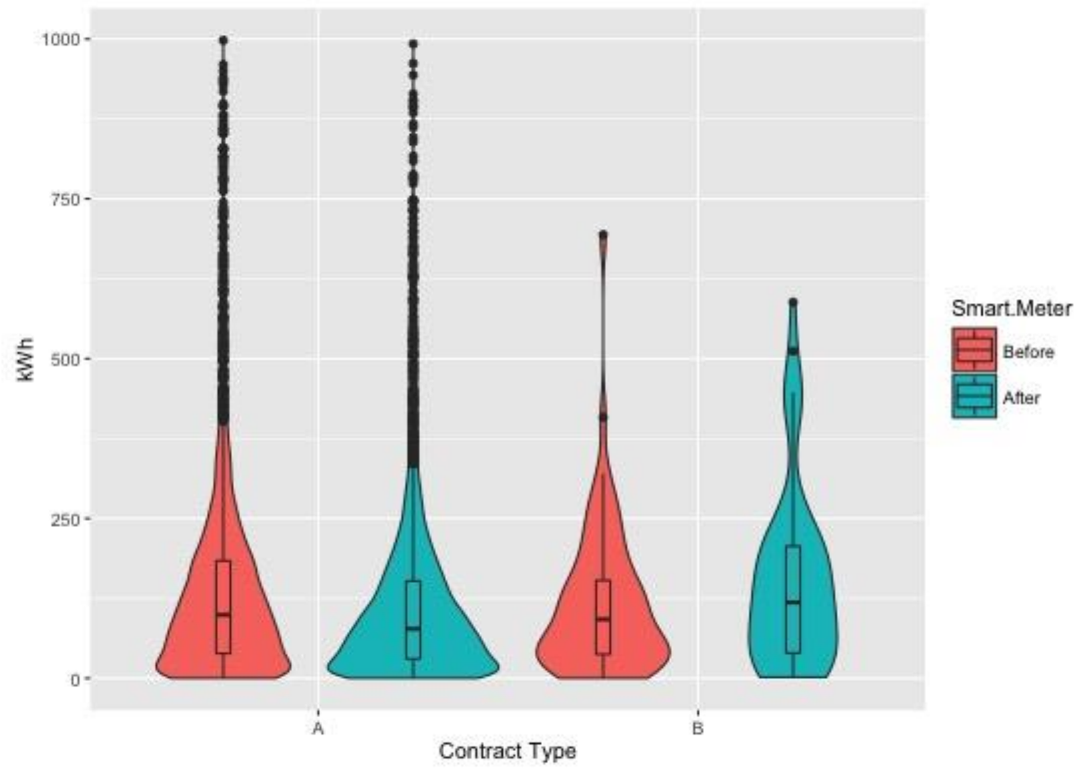

Figure 51 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 47 Average consumption (kWh/DD) of SOMENERGIA members per contract type group, before, and after installing Smart Meters.

Contract type	Sample size	Smart Meter	Avg. kWh/DD	Reduction	Reduction %
A	5958	Before	1.69	0.79	46.74%
		After	0.90		
B	61	Before	1.94	1.30	67.01%
		After	0.64		
p-value: 0.981		1.584e-12 ***			

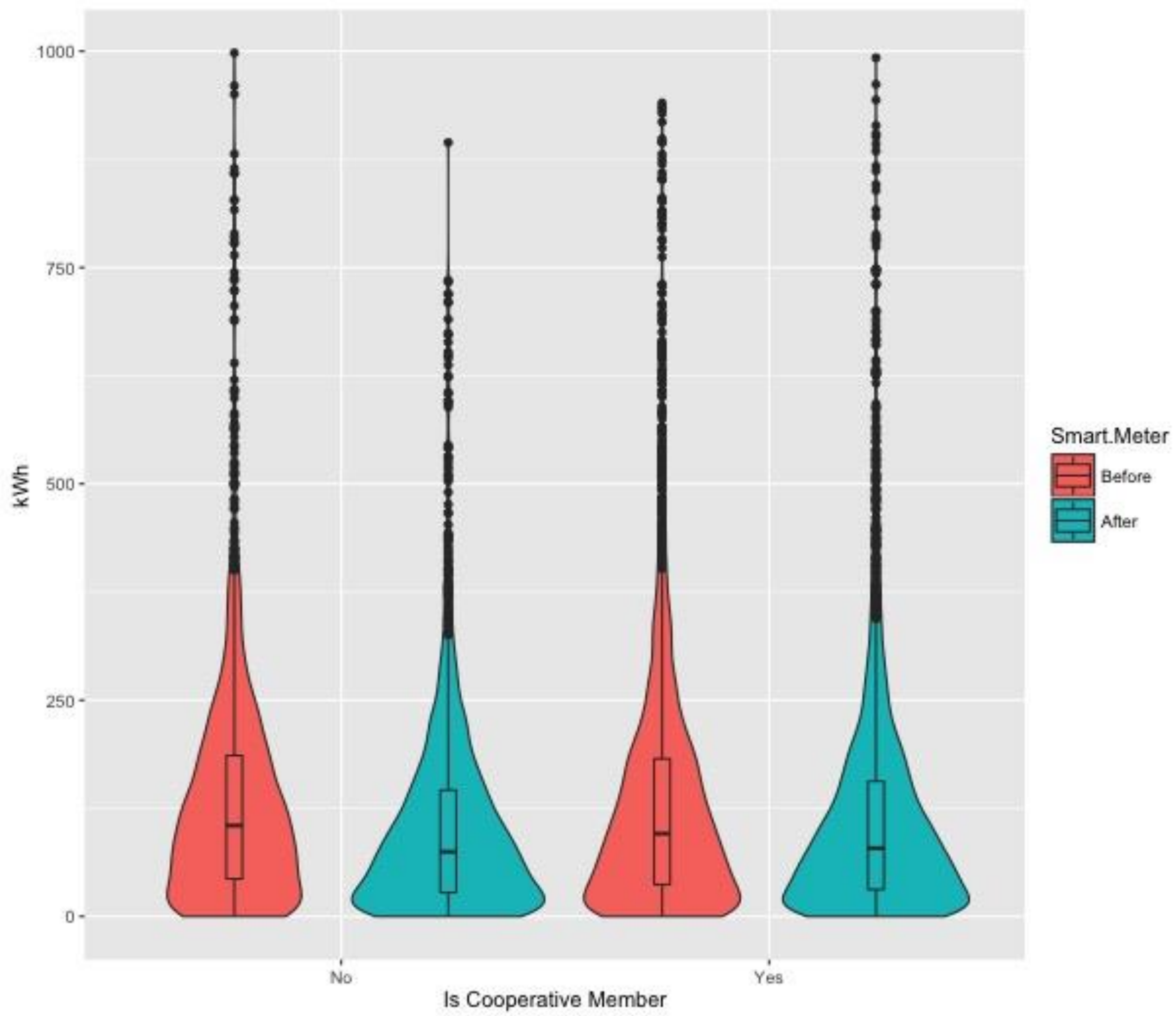

Figure 52 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 48 Average consumption (kWh/DD) of SOMENERGIA members per cooperative membership group, before, and after installing Smart Meters.

Is Cooperative Member	Sample size	Smart Meter	Avg. kWh/DD	Reduction	Reduction %
No	2001	Before	1.55	0.78	50.32%
		After	0.77		
Yes	4018	Before	1.77	0.8	45.19%
		After	0.97		
p-value: 0.081.		1.553e-12 ***			

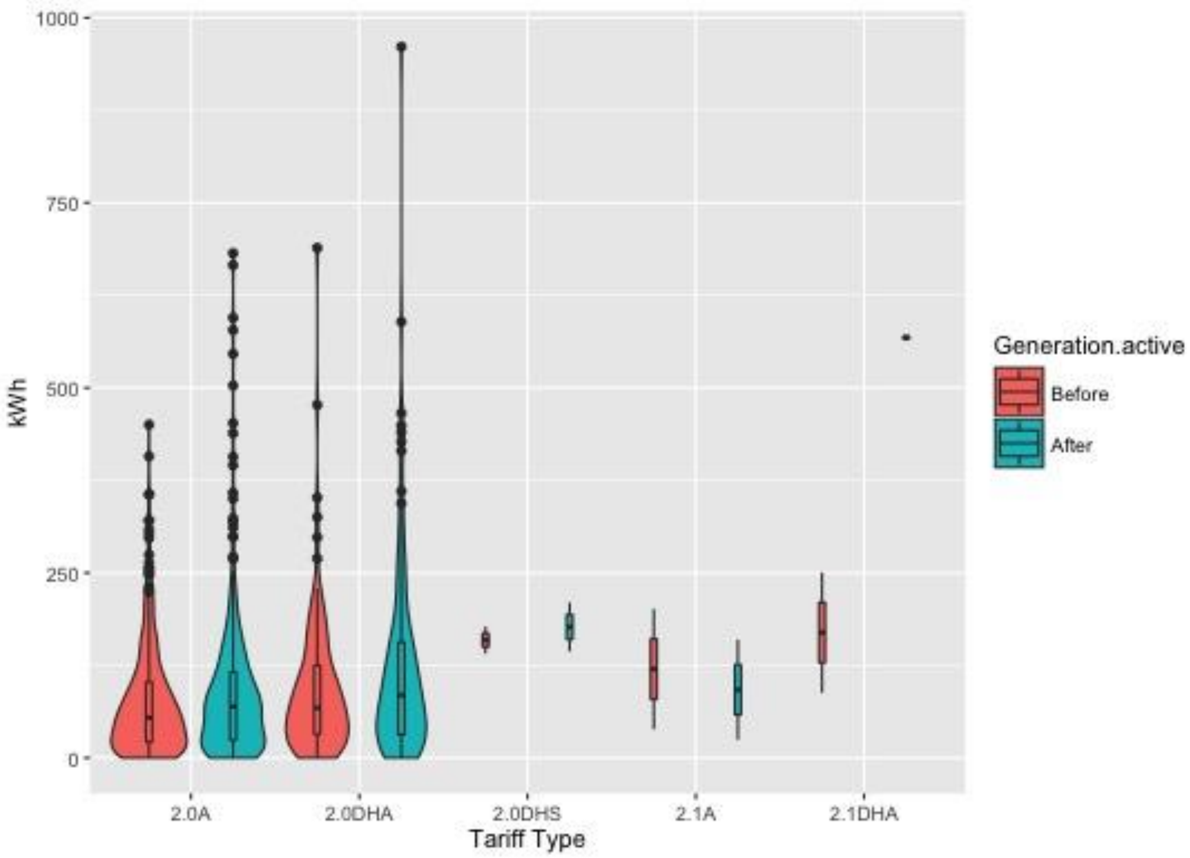

Figure 5323 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 49 Average consumption (kWh/DD) of SOMENERGIA members per tariff type group, before, and after registering to Generation Active.

Tariff type	Sample size	Generation Active	Avg. kWh/DD	Reduction	Reduction %
2.0A	354	Before	1.26	0.79	62.69%
		After	0.47		
2.0DHA	131	Before	1.50	0.96	64.00%
		After	0.54		
2.0DHS	2	Before	1.07	0.43	40.18%
		After	0.64		
2.1A	2	Before	0.84	0.44	52.38%
		After	0.40		
2.1DHA	2	Before	1.11	-1.31	-118.01%
		After	2.42		
p-value: 0.945		6.907e-05 ***			

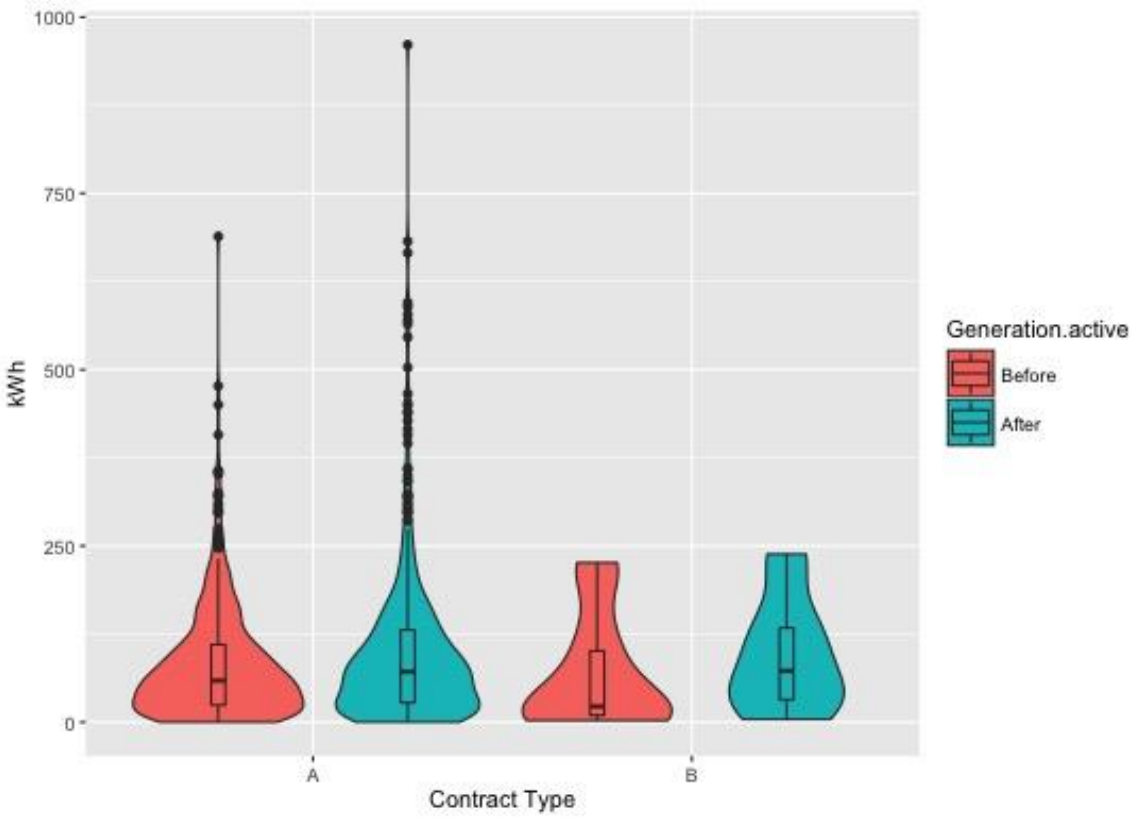

Figure 5424 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 50 Average consumption (kWh/DD) of SOMENERGIA members per contract type group, before, and after subscribing to Generation Active.

Contract type	Sample size	Generation Active	Avg. kWh/DD	Reduction	Reduction %
A	479	Before	1.31	0.81	61.83%
		After	0.50		
B	12	Before	1.79	1.39	77.65%
		After	0.40		
p-value: 0.772		6.578e-05 ***			

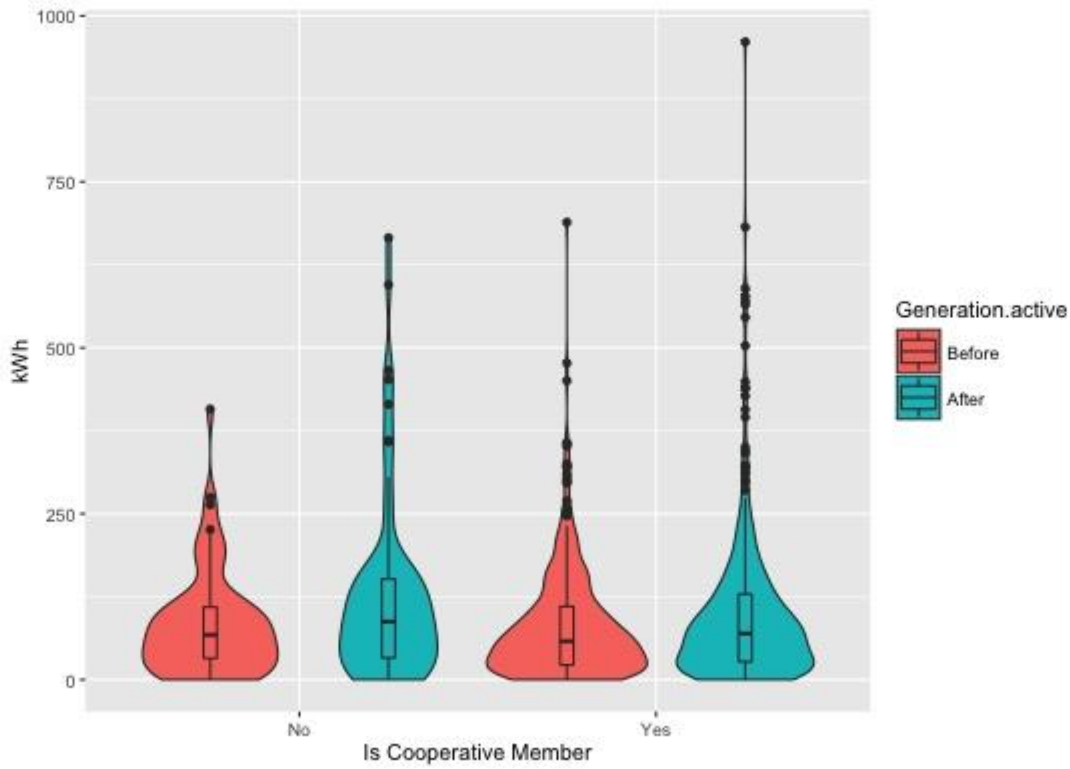

Figure 55 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 51 Average consumption (kWh/DD) of SOMENERGIA members per contract type group, before, and after subscribing to Generation Active.

Cooperative Member	Sample size	Generation Active	Avg. kWh/HDD	Reduction	Reduction %
No	66	Before	1.24	0.72	58.06%
		After	0.52		
Yes	425	Before	1.33	0.84	63.15%
		After	0.49		
p-value: 0.914		6.589e-05 ***			

EE Intervention Application Impacts (Empowering Active)

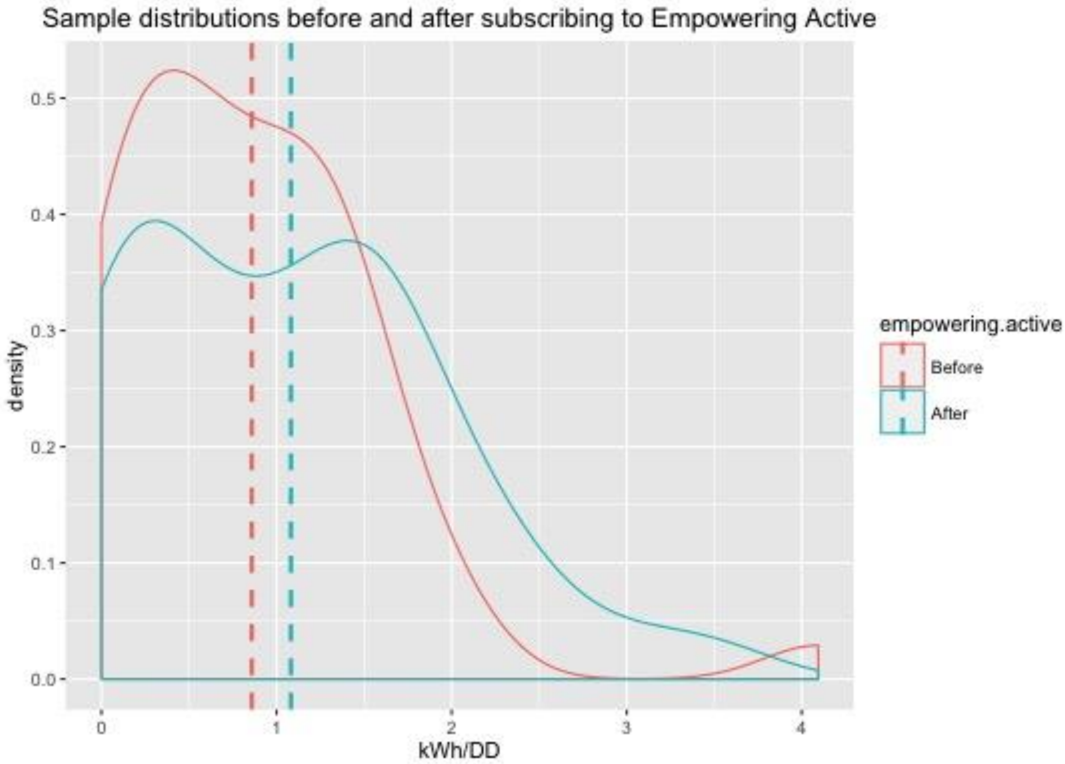

Figure 5625 Kernel Density estimates of electricity consumption in kWh/Degree Day samples for all SOMENERGIA members, before, and after registering for Empowering Active. Dashed horizontal lines represent the average of each sample group.

Table 52 Average consumption values, reductions, and significance tests, before, and after registering Empowering Active.

		Electricity Consumption	
Empowering Active	Sample size	Avg. monthly kWh	Avg. monthly kWh/DD
Before Subscription	44	163.23	0.85
After Subscription	44	175.85	1.08
Reduction		-12.62	-0.23
Reduction (%)		-7.73	-27.05
Estimated CO_2 reductions / typical customer (kg)		-15.26	
p-value		4.709e-08 ***	0.6844
Kendall's tau		0.707	0.791

In Figure 56, we observe that subscribing to Empowering Active had a negative effect on the customer of SOMENERGIA, since the blue dashed line (after) indicates a greater value than the one that the dashed red line (before) does. In Table 52, we see that the percentage reduction in monthly electricity consumption in kWh was -7.73%, and the percentage reduction in monthly kWh/DD was -27.05%.

However, the p-value of the ANOVA test on the impact of subscription on Empowering Active is 0.6844, and thus it suggests that subscription on Empowering Active does not have a statistically significant impact on monthly kWh/DD. The small sample size, which is only 44, suggests that more data should be provided regarding this EE intervention measure in order to be able to reach to more meaningful conclusions.

By the additional results shown in Appendix – Somenergia, we can conclude that the Empowering Active EE intervention measure has not significant impacts on consumption reductions for all customer groups.

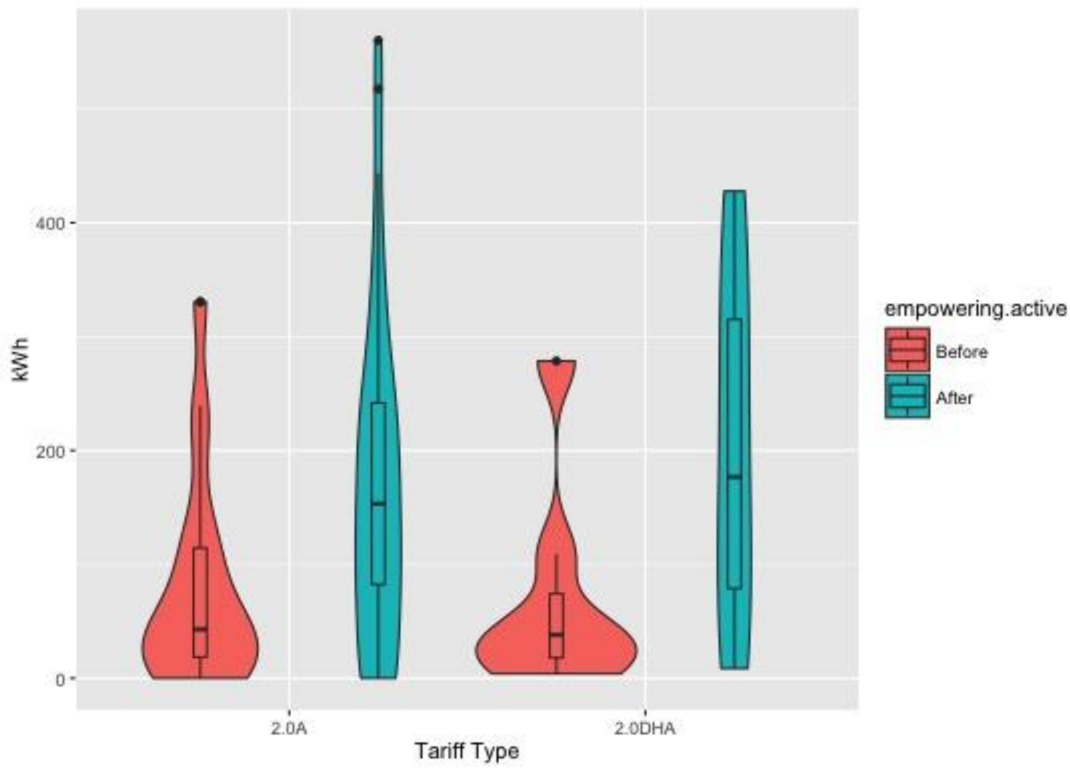

Figure 5726 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 53 Average consumption (kWh/DD) of SOMENERGIA members per tariff type group, before, and after registering to Empowering Active.

Tariff type	Sample size	Empowering Active	Avg. kWh/HDD	Reduction	Reduction %
2.0A	32	Before	1.48	0.31	20.94%
		After	1.17		
2.0DHA	7	Before	0.48	-0.63	-131.25%
		After	1.11		
p-value: 0.319		0.708			

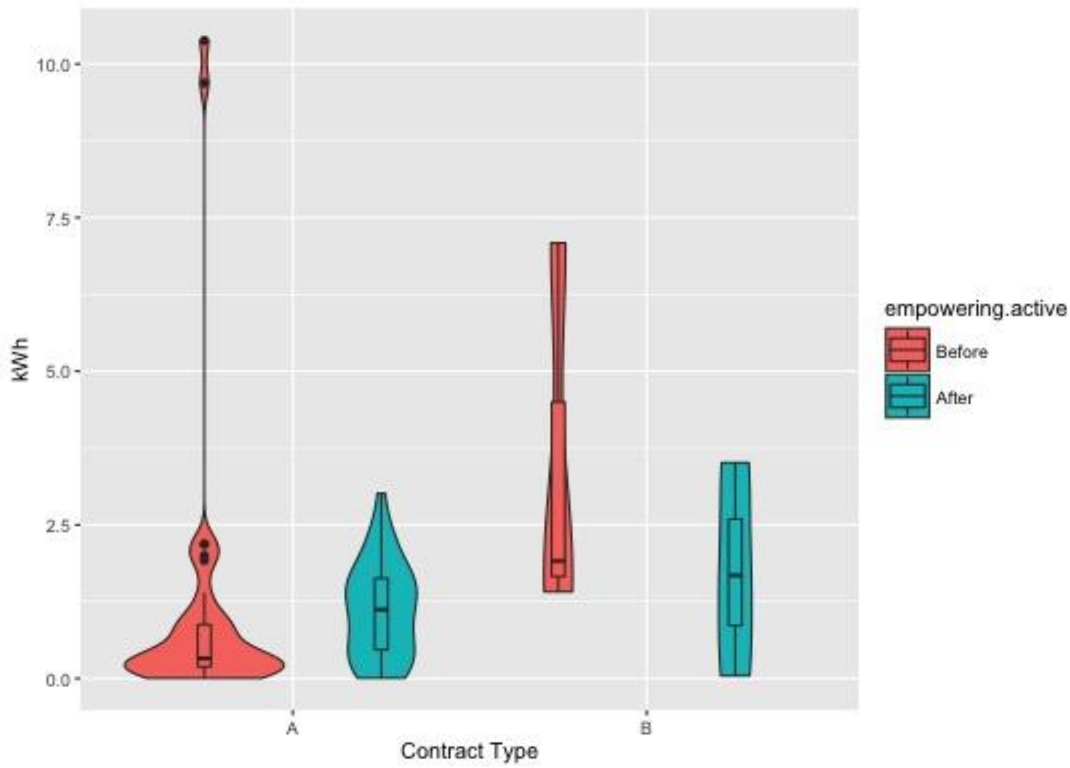

Figure 58 27 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 54 Average consumption (kWh/DD) of SOMENERGIA members per contract type group, before, and after subscribing to Empowering Active.

Contract type	Sample size	Empowering Active	Avg. kWh/HDD	Reduction	Reduction %
A	36	Before	1.12	0.01	0.89%
		After	1.11		
B	3	Before	3.47	1.73	49.85%
		After	1.74		
p-value: 0.0475		0.721			

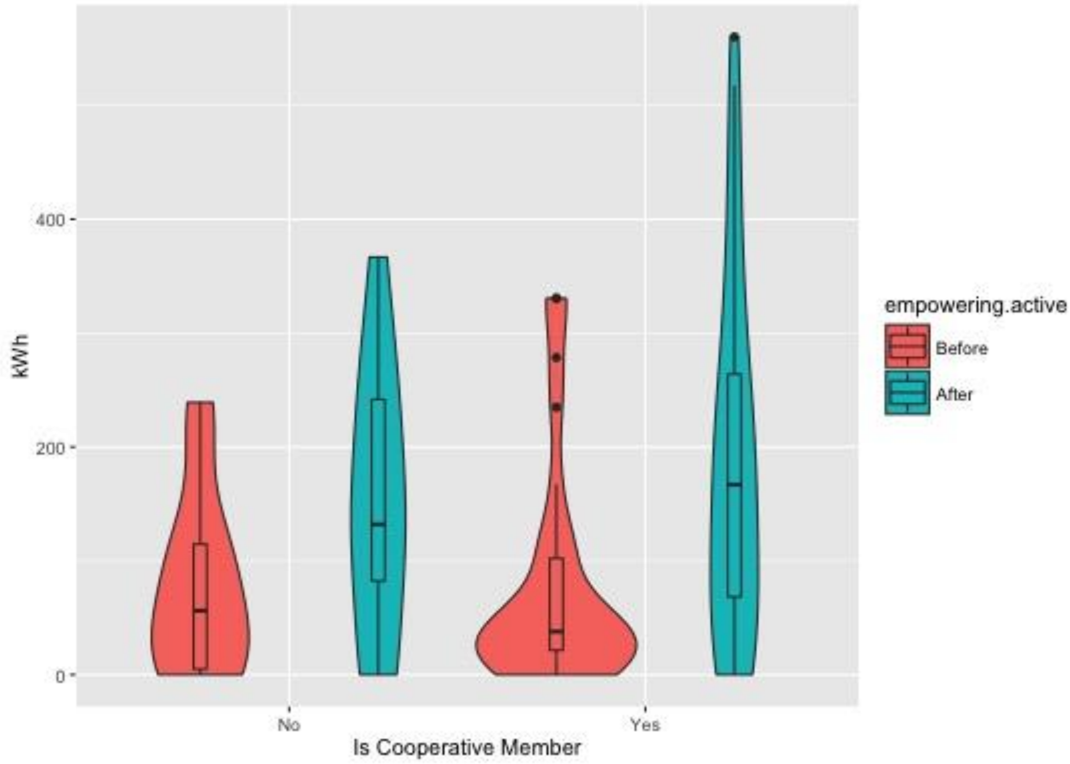

Figure 59 Violin plots without outliers with more than 1000 kWh monthly consumption

Table 55 Average consumption (kWh/DD) of SOMENERGIA members per contract type group, before, and after subscribing to Generation Active.

Cooperative Member	Sample size	Empowering Active	Avg. kWh/HDD	Reduction	Reduction %
No	12	Before	0.68	-0.26	-38.23%
		After	0.94		
Yes	29	Before	1.54	0.29	18.83%
		After	1.25		
p-value: 0.194		0.728			