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Article

Analysis of the Energy Consumption Behavior of European RES Cooperative Members

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Abstract: REScoops are cooperatives of renewable energy producers and/or consumers that are being formed in the developing European Smart Grid. Today, there are more than 2397 REScoops with more than 650,000 members. Their development indicates the necessity of producing and consuming green energy, assists the fight against energy poverty, and reduces greenhouse gas emissions by utilizing smart management systems and self-consumption techniques. An essential objective of the H2020 REScoop Plus project is to stimulate better understanding and promote the cooperatives' commitment to behavioral change. To achieve such a goal, this paper presents the methodology adopted to assess the energy-saving activities and behavior of the REScoops. In order to obtain relevant conclusions, a detailed statistical analysis was undertaken. Moreover, the analysis led to an effective classification of the various members, providing insights regarding their contribution to consumption reduction according to various specific characteristics. The statistical analysis showed that REScoop members contribute significantly to energy conservation and the reduction of harmful gas emissions, and subsequently, the majority of the energy efficiency (EE) interventions led to achieving more than 20% reductions. Specific practices, already adopted by the REScoops, lead to increased energy efficiency and environmental benefits.

Keywords: REScoops; EE interventions; actual consumption reduction; renewable energy cooperatives; performance analysis

1. Introduction

Global energy demand has risen to an unprecedented degree over the past century. Almost three-quarters of the energy consumed worldwide rely on fossil fuels. The burning of fossil fuels is a major contributor to the climate change negatively impacting humankind. In a European context, the term fuel poverty has become to define households not able to heat their houses sufficiently due to the high cost [1]. With the increasing pollution of the biosphere, the development of renewable energy (RE) has become a major societal challenge. Though increasing the share of RE is high on the policy agenda, the general public had been slow to adopt it [2] since the formation of REScoops. On the other hand, one of the most noteworthy parts of the existing energy market is the European renewable energy sources cooperatives (REScoops) [3]. This definition has been adopted from the International Cooperative Alliance (ICA) Statement on Cooperative Identity 1995, thus it represents 1 billion members of cooperatives worldwide. Cooperatives have a number of competitive benefits in producing, providing and distributing energy. They are often community-based organizations, and consequently, they deliver democratic local control over energy issues. They can also negotiate an effective model for rural electrification and can effectively connect locally available, decentralized renewable energy [4].

The year 2012 was both the United Nations International Year of Cooperatives and the United Nations International Year of Sustainable EnergyEnergy is a growth matter, and guaranteeing that people have access to a satisfactory supply of high-quality energy is vital to achieving sustainable economic, social and environmental growth. Therefore, energy cooperatives were regarded as drivers of sustainable growth and energy poverty reduction, and access to energy was also regarded as a critical issue for development processes [4].

Cooperatives serve broad geographical areas, thus making them reliable in providing their members with sufficient high-quality electric power. They are able to keep the frequency and the duration of power outages low, due to both their expertise in rural electricity and their incentive to invest regularly in the improvement and repair of their technology equipment [5].

The formation of REScoops in the European Union began some years ago, providing their members the opportunity to buy renewably generated electricity at fair prices, to interact democratically with other members and co-decide the cooperative's future, and to be autonomous and independent with respect to energy [6–8].

Hundreds of energy cooperatives are now active in Europe, the USA and Australia. Several of these represent successful instances of an approach towards energy independence for their communities and the development of the local economies regarding the –misuse of domestic energy sources. Sifnos Island Cooperative has initiated an effort to claim the energy independence of the insular community on the autonomous island of Sifnos in Greece [9].

Today, there are more than 2397 REScoops, with more than 650,000 members [10–12]. Citizens jointly investing in and operating renewable energy installations, through renewable energy cooperatives, play an essential role in some European countries [13]. Residential solar system installations make up a significant portion of the overall solar growth [14] and through REScoops' actions, this is due to increase further in the near future. For example, Spanish renewable energy sources (RES) cooperatives frequently join forces in sharing education courses and experiences, while also trying to spread new ideas at both social and political levels. However, notwithstanding their growth and regional spread over the last few years, RES cooperatives still have a minor presence in the Spanish energy system [15,16].

In addition, there are some optimistic scenarios in which every city implements a renewable energy cooperative; for example, it is projected that in the Port of Rotterdam, once the first renewable energy systems are implemented, with the aid of smart business models, the initial financial situation of the cooperative will steadily be upgraded and with these funds, it will be able to expand its staff to increase its impact and lead the energy transition in the port [17].

Growing concerns about climate change impacts on humans and eco-systems are motivating the exploration of new strategies to complement traditional climate policies such as mitigation and adaptation [18]. Energy cooperatives have been an important building block in the energy transition in various European countries, although their practical importance is neither quantitatively nor qualitatively reflected in the academic literature [19]. The systematic design of an energy supply/demand structure has become an increasingly important issue relating to sustainability [20].

Although the activities that REScoops undertake, resemble those of other organizations to some extent and due to their particular organizational and business models as citizens' initiatives, i.e., their cooperative model, REScoops are thought to be very well-positioned to undertake activities to influence and help their members to save energy. Given these features and benefits, REScoops organize events, such as meetings and conventions in order to raise their members' energy awareness [11,21].

As an outcome, it is expected that when end-users participate in an energy cooperative, they become more thoughtful regarding energy conservation and efficiency [16,22]. To this end, the REScoop Plus project aims to gather available information and data from various European

REScoops, and demonstrate that participation in such a cooperative raises energy awareness and contributes to accomplishing the challenging goal of energy efficiency [10,23].

On the other hand, renewable energy cooperatives may face some difficulties, such as capital market regulation, a lack of full-time staff, a lack of active voluntary involvement, the transformation of business models, financing, etc. These may act as inhibiting factors that not only threaten the cooperatives' aims but also impact the emotional health of the people who are actively involved. Such impacts may result in frustration, helplessness and a sense of being overwhelmed. It is apparent that local support and help is of high importance for cooperatives in order to operate smoothly [23,24].

This paper focuses on describing the process by which energy conservation and efficiency can be investigated from an informational (data-centered) point of view. The outcomes of the statistical analysis showed that REScoop members contributed significantly to energy conservation and the reduction of harmful gas emissions. Also, the adoption of specific practices led to increased energy efficiency and environmental benefits. There is insufficient literature regarding REScoops and the existing studies do not provide data and results regarding the behavior of their customers and members. This paper takes a forward-thinking approach in providing, for the first time, a systematic behavioral analysis of REScoops' customers, as presented in the results section.

2. Presentation of the Methodology

2.1. Main Steps

The core aim of this work was to statistically evaluate: (a) the impacts of proposed energy efficiency (EE) interventions in terms of decreased energy consumption; and (b) underline the most effective EE interventions in a recommendations toolkit. This toolkit can be considered as a practical guide for newly formed cooperatives, in order to achieve even better performance in meeting energy consumption reduction targets. The following steps were taken to achieve these goals:

1. Share information and knowledge regarding data storage and handling, and consumption reduction behavior, among REScoops.
2. Identify and record existing datasets and their formats.
3. Determine a common data format for all cooperatives. This included the definition of a data structure, as well as the fields that would contain the various measurements.
4. Gather the available datasets of the supplying REScoops (questionnaire, survey, interviews, and meetings with the data experts).
5. Initial statistical analysis of the historical data before the initiation of the REScoop Plus project. This step would give us a first glimpse of what generally happened to the consumption of the cooperative members, and how existing EE interventions were being applied. The results would help identify:
    (a) Whether reduction was indeed taking place in REScoops;
    (b) Potential key factors for consumption reduction.

Then, the following factors were taken into consideration to help identify good behavioral practices and EE interventions

1. Application of specific EE interventions to certain members and groups of members.
2. Gathering available datasets after the application of the EE interventions.
3. Final statistical analysis of the impact of each EE measure on the consumption of end-users.

These steps characterized the efficiency of each proposed EE intervention and helped enrich the recommendations toolkit offered to REScoops.

2.2. Data Collection and Pre-Processing

A critical task of our research was to collect data from REScoops over a long period after implementation of the "best energy efficiency practices" and perform a comprehensive statistical analysis in order to characterize the effectiveness of these interventions.

In the next section, the main difficulties that REScoops had in gathering and submitting the datasets and the additional pre-processing that had to be performed by the research team, are described. Seven REScoops participated in the data submission process, namely: (i) EBO from Denmark; (ii) ECOPOWER from Belgium; (iii) ENERCOOP from France; (iv) SOMENERGIA from Spain; (v) SEV from Italy; (vi) ENOSTRA (AVANZI) from Italy; and (vii) COOPERNICO from Portugal [12].

Several challenges concerning the data processing were encountered during the analysis (e.g., some REScoops were new, while others improved their data collection system during the project). The problems were dealt with by filling in for missing data (whenever this was possible following accepted statistical techniques), creating new variables and using the most appropriate statistical tests/indexes per case.

Regarding the young cooperatives, ENOSTRA and COOPERNICO, had short customer-member lists, since they were newly formed. We must note that, in general, newly formed REScoops faced many vital tasks regarding the cooperative's constitution, the need to overcome legal barriers where these exist etc., so their expansion to new customers and members may have been of secondary concern in this early stage. In addition, automatized systems for data collection and analysis were not set up, thus the process was quite time-consuming as it had to be performed manually. Often this meant having to combine different data sources; e.g., by analyzing the data of the Distribution System Operator (DSO) and extracting consumption information from the billing system. Nevertheless, both cooperatives contributed to our research, by submitting their available measurements.

Regarding the older and more established cooperatives, important challenges existed there too. First of all, their data collection and storage systems did not share a common data format and data restructuring was imperative in most cases. Also, the granularity of the stored measurements varied from 15-min intervals to yearly values. We stressed that monthly values would be best for the purpose of the project, due to the restricted time horizon of REScoop Plus. However, in cases where monthly data were not available, the analysis was performed using semi-annual or/and yearly measurements.

Another difficulty the research team (and REScoops) faced was the retrieval of meteorological data. Being mainly energy companies, the REScoops rarely stored 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 with the successful submission of meteorological data. For the remaining REScoops, the research team filled in the missing meteorological data wherever possible by exploiting globally accepted tools, such as METEONORM™.

The most difficult part of the data collection procedure turned out to be the submission of demographic data. Values such as the building's surface in square meters, as well as the number of residents, were very important for acquiring the normalized consumption indices. These indices were necessary for reasonable analysis and comparison (e.g., of electricity consumption) among REScoops. The main issue with the collection of such data was 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/business. Despite this fact, most REScoops submitted demographics. For the rest of the REScoops, the research team filled in the missing demographic data (apart from a few cases where this was indeed impossible to obtain).

Finally, the size of the datasets submitted was not a serious problem in the statistical analysis.

2.3. Statistical Analysis

The purpose of this section is to provide information/knowledge regarding the key part of this report. Specifically, the methods that were utilized in order to carry out the statistical data analysis, the typical values that were computed, the characteristics according to which certain groupings of the population were performed, and the way in which the reduction of electricity consumption was estimated, with respect to several intervention measures.

2.3.1. Calculation of Typical Values

We computed the average value of energy consumption in kWh for various groups, by summing across the values of all relevant measurements and then dividing by their total number (sample size). Thus, the computed average values are un-weighted. Furthermore, in order to gain better insight into energy consumption, we also performed normalization with respect to other characteristics, e.g., the number of residents. Such normalization is important when the monthly energy consumption, in kWh, varies among different households due to factors such as the number of inhabitants, the geographical region of residence etc. In some cases, we conducted normalization with respect to two features, e.g., heating degree days (HDD) and m^2. This was performed by dividing the energy consumption measurement in kWh by the product of the values of the two features. Specifically, we calculated indices such as:

- Average monthly electricity consumption in kWh normalized by heating degree days (Avg. kWh/HDD);
- Average monthly heating energy consumption in kWh normalized by HDDs (Avg. kWh/HDD).

2.3.2. Population Division in Groups

Naturally, a population of interest is not homogeneous with respect to various characteristics. Therefore, it is meaningful to divide the population into distinct groups and try to compare these groups w.r.t different characteristics/variables. In the context of our statistical analysis, the most meaningful differentiation was according to whether a consumer had received an energy efficiency intervention or not. However, in our statistical analysis we also performed a number of group divisions, according to the following features:

- Cooperative and non-cooperative members;
- Energy efficiency measure:
    - Leaflets
    - Technical support
    - Software solutions
    - Engagement activities
    - Smart metering installation;
- Tariffs:
    - Special
    - Flat
    - Time of use.

Note that this list was populated according to the available data submitted by the REScoops, and may 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 (Zero-point report on data of Supplying REScoops) and D2.2 (Methodology for Analysis), and to data availability for each new REScoop, i.e., which measurements they store.

2.3.3. Reductions Calculation

In order to estimate the impact of the interventions on energy consumption, the energy reduction before and after their application and after their application was calculated. The reductions were computed in both absolute values and percentages in order to evaluate their importance.

2.3.4. Statistical Methods

In our statistical-analysis we used two statistical methods/measures, namely ANOVA [25] and correlation coefficients (Pearson's correlation coefficient and Kendall's tau coefficient [26]) which provided us with valuable information mainly regarding the impact of EE interventions on the kWh consumption.

We used two correlation coefficients:

- The Pearson product-moment correlation coefficient (r, R, or Pearson's r) is a measure of the strength and direction of the linear relationship between two quantitative variables (e.g., actual consumption and monthly bill charged). For its computation, several assumptions needed to be satisfied (namely, level of measurement, related pairs, absence of outliers, normality of the dependent variable, linearity and homoscedasticity).
- Kendall's tau (nonparametric) coefficient was used to measure the relationship between rankings of ordinal variables.

In addition, the non-parametric Chi-Square test of independence was used several times to determine if there was a significant relationship between two nominal (categorical) variables (e.g., meteorological region and smart metering installation users). The data were displayed in a contingency table. The null hypothesis for the test was that there was no association between the two variables/characteristics.

The critical value for the chi-square statistic is determined by the level of significance (typically 0.05) and the degrees of freedom. If the observed chi-square test statistic is greater than the critical value (or the *p*-value is less than 0.05), the null hypothesis can be rejected [25,26].

3. Results

The results of the statistical-analysis on the impacts of EE interventions on the energy demands of the clients of each REScoop are presented below.

3.1. SEV—Italy

SEV is a cooperative from Italy originally founded in 1998. It is an association of renewable energy producers and distributors in the South Tyrolean area and is governed as a cooperative. Its 300 members are producers and distributors of heat and electricity. Most of them are cooperatives, some public and others private. Ten people worked directly for SEV; however, including the members, hundreds of people were involved in supplying and producing clean energy [22].

The results presented were derived from the statistical analyses of two (2) representative customers (schools), indicated by Best Practice 1 and Best Practice 2. Highlights of the dataset are presented in Table 1.

The proposed interventions were a combination of (a) a smart meter installation, and (b) the hydraulic balance of optimal temperature.

Table 1. Highlights of SEV's dataset.

a/a	Best Practice 1	Best Practice 2
Period of measurements	09/2005–08/2018	09/2002–06/2018
Number of months	156	190
of which EE intervention was in use	102 (65.4%)	139 (73.2%)
No of interventions	2 (combined to 1)	2 (combined to 1)
Meteorological data	Yes	Yes
Mean monthly actual consumption (kWh)	44,878	42,915
Average monthly bill (€)	2571	2870
Consumption groups	Actual consumption concerning the amount of heat, EE Intervention (before and after)	Actual consumption concerning the amount of heat, EE Intervention (before and after)

3.1.1. Best Practice 1

Best Practice 1 (BP1) was a school for which SEV provided 156 monthly measurements, 102 of which were during the use of their proposed intervention.

The actual consumption is a periodic time series (12-month period) with the maximum occurring in December/January and the minimum in June (Figure 1). There is a noticeable decrease in actual consumption in the winters of 2014, 2015, and 2016.

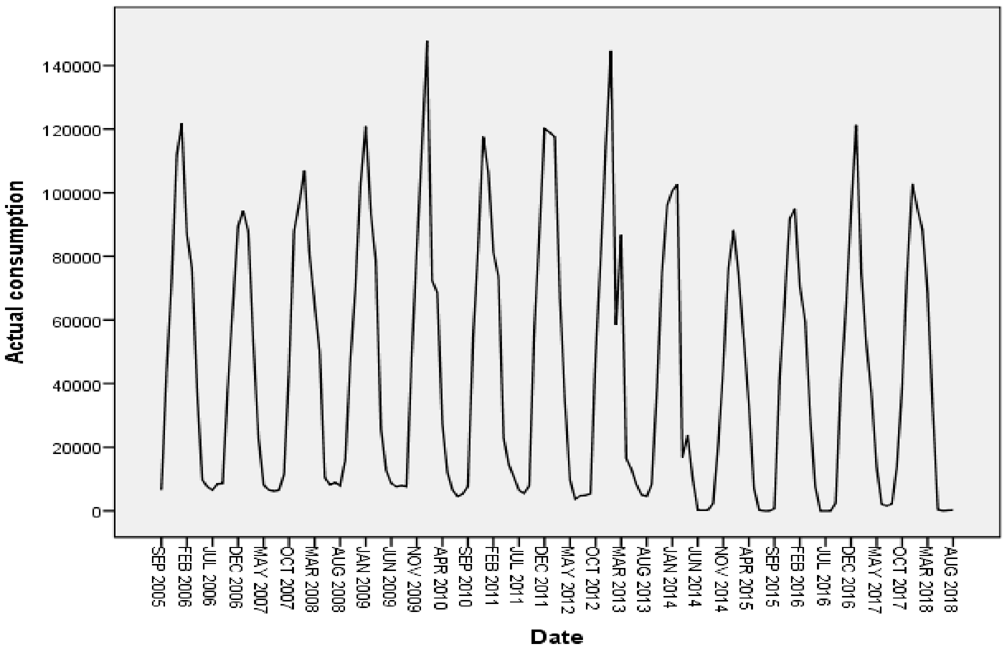

Figure 1. Time series of actual consumption for Best Practice 1 (BP1).

There was a strong, statistically significant, negative correlation, between actual consumption and the average daily temperature (r = −0.594, sig = 0.000, α = 0.05); i.e., an increase in average daily temperature was followed (usually) by a decrease in actual consumption. There was also a noticeable difference in actual consumption before and after implementation of the proposed EE intervention (27.8% reduction in energy consumption) and this can be converted into 5.57 $tnCO_2$. That is, there was a statistically significant difference (sig = 0.042, α = 0.10) in actual consumption between the months without the EE intervention and the months with the EE intervention (49,659 compared to 35,847 kWh).

3.1.2. Best Practice 2

Best Practice 2 (BP2) was also a school for which SEV provided 190 monthly measurements, 139 of which were during their proposed intervention use.

The actual consumption is also a periodic time series (12-month period) with the maximum occurring in December/January and the minimum in June (Figure 2). There was a noticeable decrease in actual consumption in the winters of 2014, 2015, and 2016.

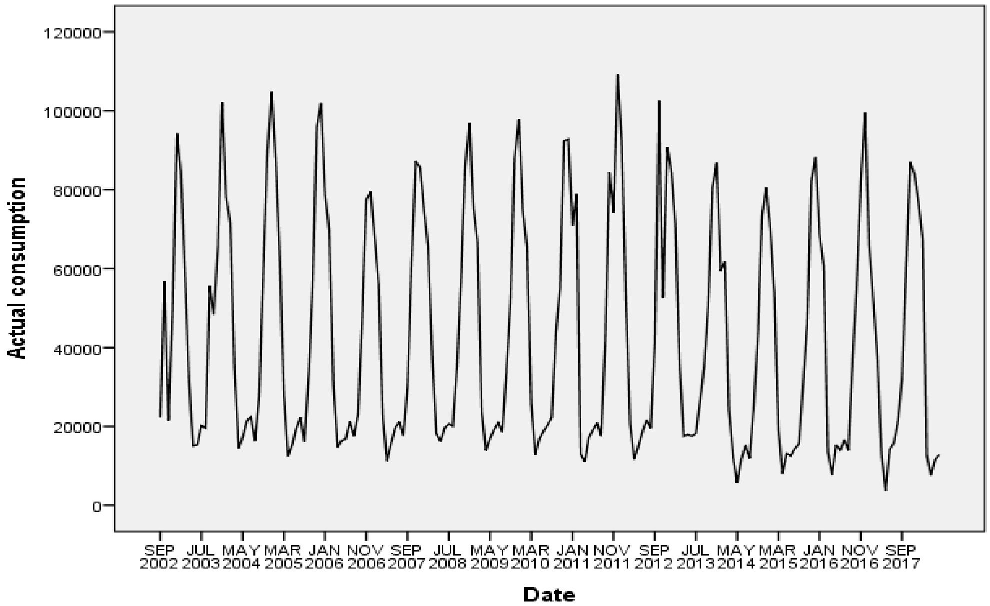

Figure 2. Time series of actual consumption for Best Practice 2 (BP2).

There was also a strong, statistically significant, negative correlation, between actual consumption and average daily temperature ($r = -0.506$, sig = 0.000, $\alpha = 0.05$); i.e., an increase in average daily temperature was followed (usually) by a decrease in actual consumption.

There is also a noticeable difference in actual consumption before and after implementation of the proposed EE intervention (17.6% reduction in energy consumption) and this can be converted into 3.21 $tnCO_2$. That is, there was a statistically significant difference (sig = 0.099, $\alpha = 0.10$) in actual consumption between the months without the EE intervention and the months with the EE intervention (45,047 to 37,106 kWh).

This difference, in actual consumption, for both customers, can be seen in Figure 3.

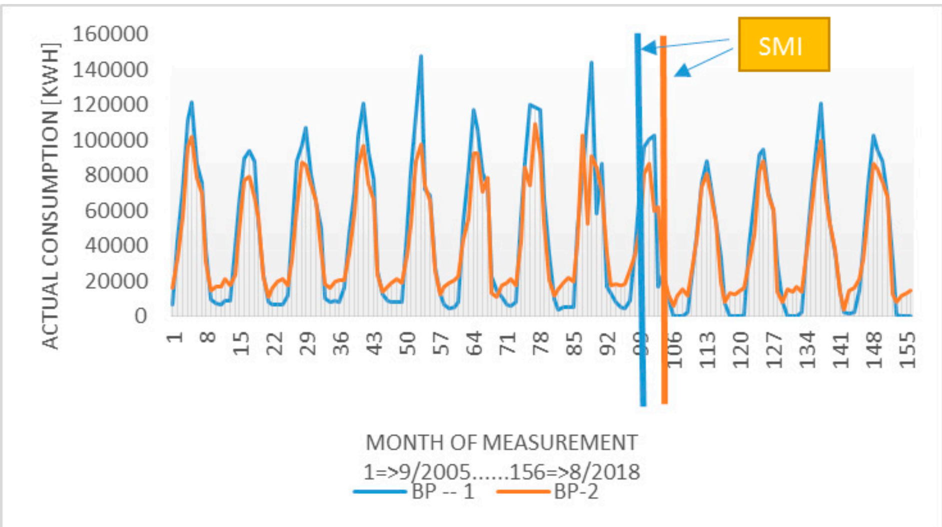

Figure 3. Comparison of actual consumption for BP1 and BP2 customers.

3.2. Coopérnico—Portugal

Coopérnico is a newly-formed cooperative of renewable energies from Portugal, founded by a group of 16 citizens from different professional backgrounds, but who share a common concern: sustainable development. Their vision is a renewable, fair and responsible energy model that contributes to a socially, environmentally and energetically sustainable future and their mission is to involve citizens and companies in creating the new energy paradigm renewable and decentralized for the benefit of society and the environment [22].

Coopérnico did not propose an intervention but used a technique regarding the cost of the energy, namely, special tariffs. Three types of tariffs were used: (a) BTN Simples; (b) BTN Bi-Horário; and (c) BTN Tri-Horário. Highlights of the dataset are presented in Table 2.

Table 2. Highlights of Coopérnico's dataset.

Period of measurements	06/2015–06/2018
Number of measurements	9441
Number of months	37
Types of customers	2
Number of interventions	1 (special tariffs)
Number of tariffs	3
Meteorological regions—Zones	2
Mean monthly actual consumption	301.34 kWh
Clustered groups	Type, Zones, Tariffs, Contracted power

Data for two customer types were provided: (a) Particular, 86.2% of the total number of customers; and (b) Empresa (Company), 13.8% of the total number of customers (in 2018). Empresa customers consumed (almost) four times more energy (773 to 206 kWh).

We compared the actual consumption among the different tariff types as this is a useful indicator regarding the efficiency of the proposed charging technique (Figure 4).

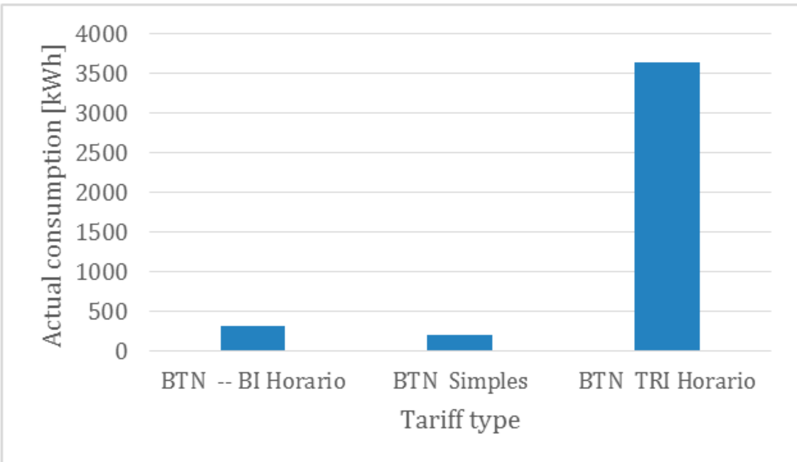

Figure 4. Actual consumption by tariff type.

There was a statistically significant difference in actual consumption between Bi-Horario, Simples and Tri-Horario tariff customers (sig = 0.000) in 2017 (308.8, 205.6 and 3651 kWh, respectively). Customers with the Tri-Horario tariff had the highest energy-consumption and customers with the Simples tariff had the lowest energy consumption. The majority of the customers of both types, Particular and Empresa, were being charged with the Simples tariff (61.9 and 73.3%, respectively) in 2017.

A grouping regarding contracted power was also performed in order to obtain additional results. The most energy-demanding category was the one with 41.4 kW contracted power while the category that was the least energy dependent was the first category of 3.45 kW contracted power. There was a statistically significant difference in actual consumption between the different power customer groups (sig = 0.000 < 0.05) for 2017 (i.e., as the contracted power increased, the actual consumption also increased) (Table 3).

Table 3. Categories of contracted power and mean actual consumption.

Category—Contracted Power [kW]	Mean Actual Consumption
3.45	135.95
4.60	185.74
5.75	239.06
6.90	250.74
10.35	363.52
13.80	492.57
17.25	639.35
20.70	779.17
27.60	2233.20
34.50	2318.42
41.40	5142.39

Using a chi-square test we found that the variables “tariff” and “Contracted power kWh” were dependent meaning that the tariff being charged depended on the contracted power kWh category customers belonged to (sig = 0.000).

3.3. *ENOSTRA—Italy*

ENOSTRA is a non-profit cooperative from Italy (an electricity supplier) which, sells only renewable electricity from photovoltaic, wind and hydroelectric plants to its members. ENOSTRA offers members efficiency improvement services, the realization of photovoltaic systems and monitoring of (reduced) consumption. Furthermore, they provide opportunities for the participation and involvement of individuals and social networks in support of the energy transition [22]. Highlights of the dataset are presented in Table 4.

Table 4. Highlights of ENOSTRA’s dataset.

Period of measurements	08/2017–07/2018 or 09/2017–08/2018
Number of measurements	3462 to 3461 (304 customers)
Number of months	12
Number of interventions	2 (Special tariffs and EE leaflets)
Number of tariffs	2
Meteorological regions—Zones	4
Production data	Yes (2.8% of total customers)
Meteorological data	Yes
Demographics	Yes
Mean monthly actual consumption	150.61 kWh
Clustered groups	Zones, Tariffs

ENOSTRA did not propose an intervention, but used a technique regarding the cost of the energy, namely special tariffs, and distributed EE leaflets to their customers. Two types of tariffs were used; (a) time-of-use (TOU) tariff and (b) FLAT tariff.

HDDs were proportional to actual consumption and to the monthly bill charged, with the maximum occurring in January and the minimum in June/July/August (Figure 5). There was a relatively small fluctuation in (monthly average) actual consumption (average monthly actual consumption ranged from 135 to 185 kWh).

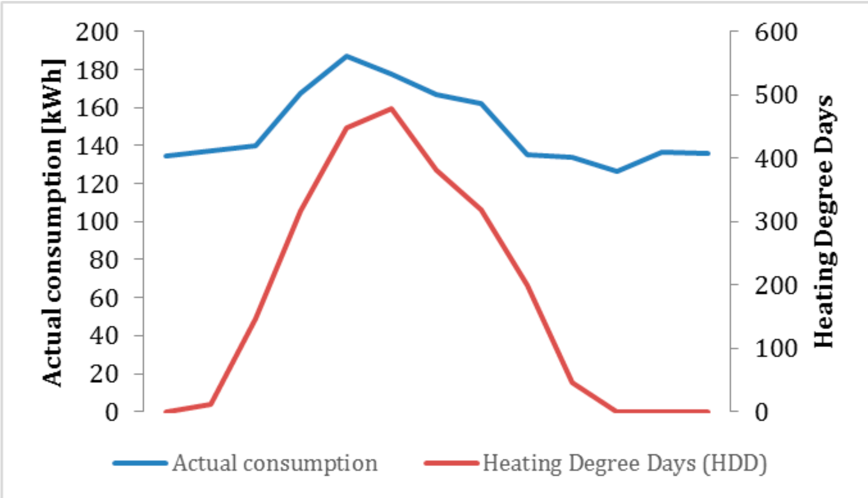

Figure 5. Actual consumption and heating degree days for the period examined.

Regarding the tariffs, there were two types: (a) the TOU tariff, and (b) the FLAT tariff. TOU stands for Time-of-Use with the cost of energy depending on the time the energy is used. The majority of customers used the TOU tariff type (72.5%) and the remainder (27.5%) used the FLAT tariff. There was a difference in actual consumption, between the two types of tariffs but this difference was not statistically, significant (ANOVA, sig = 0.556) (even though for TOU customers, average actual consumption was approximately 10 kWh higher, 159 compared to 150 kWh).

3.4. Som Energia—Spain

Som Energia is a consumer-owned cooperative. It started in 2009 with a group of students from the University of Girona. In 2018 it had around 42,000 members and 72,000 customers. Its goal is to produce as much renewable electricity as their members use. Som Energia's main activities are the commercialization and production of renewable energy and it is committed to promoting a change in the current energy model to achieve a 100% renewable model. They produce electrical energy in generating installations from renewable sources (sun, wind, biogas, biomass, etc.), financed with voluntary economic contributions from the partners [22]. Highlights of the dataset are presented in Table 5.

Table 5. Highlights of Som Energia's dataset.

Period of measurements	01/2015–08/2018
Number of measurements	862886
Number of months	44
Number of interventions	5
Production data	Yes (2.8% of total customers)
Meteorological data	Yes
Mean monthly actual consumption	• 2015: 247.34 kWh • 2016: 259.47 kWh • 2017: 261.23 kWh • 2018: 260.64 kWh
Consumption groups	Members, Interventions (5), Type

The cooperative initiated five types of interventions, including: (a) special tariffs; (b) EE leaflets; (c) smart meter installation (SMI); (d) generation action; and (e) empowering action.

There was an overall increase in the average monthly consumption through the years (from 247 to 261 kWh). Members of Som Energia consumed more, increasing from 252.5 in 2015 to 268.9 kWh in 2017. The consumption of non-members ranged from an average of 233 to an average of 244.5 kWh.

The decrease in consumption in 2018 was probably due to the fact that there were only eight months of measurements (for 2018).

Every intervention was examined regarding actual consumption before and after its implementation.

First, there was a difference in the average consumption between customers who received EE leaflets and those who did not (255 to 257.5 kWh) which translated to 1 $kgCO_2$ per customer. Even though those who received EE leaflets consumed less, the difference was not statistically significant (sig = 0.667).

Furthermore, there was a statistically significant difference (sig = 0.000) in the average consumption between users and non-users of SMI. Users of SMI consumed less energy (244 compared to 272.7 kWh for non-users). On average, SMI users consumed 30 kWh less energy, and this translated to 12.12 $kgCO_2$ per customer.

We found a statistically significant difference (sig = 0.000) in the average actual consumption between those who took part in the generation action and those who did not (195 compared to 260 kWh). Those who took part consumed 55 kWh less and this translated to 22.22 $kgCO_2$ per customer.

There was a statistically significant difference (sig = 0.000) in the average consumption between those who took part in the empowering action and those who did not (202 compared to 280 kWh). Those who took part in empowering action consumed 78 kWh less energy than those who did not and this translated to 31.51 $kgCO_2$ per customer.

Regarding tariff types, there was a statistically significant difference in actual consumption between those charged using special tariffs and those charged without s.t (sig = 0.000). Those charged using special tariffs consumed two and a half times more electricity (497 compared to 202 kWh than those charged without special tariffs).

3.5. Ecopower—Belgium

Ecopower is a cooperative company owned by more than fifty thousand cooperatives, ordinary citizens who own, together with their renewable energy installations: wind turbines, solar panels, small hydropower plants and a pellet and wood briquette plant. The cooperatives determine the policy and the future of Ecopower. Each shareholder has one vote at the annual general meeting. In this way, they invest together in a real, local and sustainable economy. Making a contribution to society is an important task for cooperatives. Ecopower does this by focusing on the energy of the future, i.e., energy saving and renewable energy [22]. Highlights of the dataset are presented in Table 6.

Table 6. Highlights of Ecopower's dataset.

Period of measurements	2011–2016
Number of measurements	194,028
Number of years	6
Number of interventions	2
Production data	Yes
Demographics	Yes
Mean monthly actual consumption	• 2011: 2524.34 kWh • 2012: 2341.35 kWh • 2013: 2169.34 kWh • 2014: 2117.87 kWh • 2015: 2049.85 kWh • 2016: 1982.96 kWh
Consumption groups	Members, Interventions (2), Type, Prosumers

Two types of interventions were used by Ecopower: (a) EE leaflets and (b) EnergieID, a type of smart metering software.

As the data contained actual consumption of more than 20,000 kWh per month, mean actual consumption was not a good indication of actual consumption. Therefore, in this case, we used the median actual consumption (Table 7).

Table 7. Median actual consumption.

Year	Median Consumption [kWh]	Reduction [%]	Reduction (Since 2012) [%]
2011	2147		
2012	1886	−12.2	−12.2
2013	1689	−10.4	−21.3
2014	1645	−2.6	−23.4
2015	1588	−3.5	−26.0
2016	1517	−4.5	−29.3

It is clear that the interventions had a substantial impact on customers' energy consumption, as consumption had reduced by almost 30% since 2012, from 2147 kWh to 1517 kWh, which translated to 254.52 $kgCO_2$ per customer annually.

First, customers who received EE leaflets tended to consume two times more energy than those who did not (7524 kWh compared to 3452 kWh, respectively). As expected, there was a statistically significant difference in total consumption between those who have received EE leaflets and those who did not (sig = 0.000). It has to be noted that EE leaflets were mainly distributed to consumers with more than 6000 kWh total consumption.

The second intervention was the implementation of EnegieID. As an initial service, EnergieID set up a SaaS-platform (software as a service) to help families and organizations to manage their energy and water consumption as well as their transport distances (km) and renewable energy production. The proportion of EnergieID users increased to 3.4% in 2016 from only 0.1% in 2013. There was a statistically significant difference in actual consumption between the customers with EnergieID and those without EnergieID (sig = 0.000). Customers with EnergieID consumed less electricity (2023 kWh compared to 2193 for those without EnergieID) which translated to almost 70 $kgCO_2$ per customer.

3.6. EBO—Denmark

EBO Consult is an independent administration company specializing in managing district heating companies. They have several district heating cooperatives under total or partial administration. EBO takes care of the economic management, operation and maintenance, customer service, energy savings, and expansion of district heating and functions as a secretariat for the district heating company. Its focus is to secure cheap, sustainable and professional solutions in the management and operation of district heating, while achieving a high level of security of supply and favourable customer satisfaction with the district heating company [22]. The highlights of the EBO dataset are presented in Table 8.

Table 8. Highlights of EBO's dataset.

Period of measurements	05/2012–08/2018
Number of measurements	25,369 (600 customers)
Number of interventions	2 (combined to 1)
Meteorological data	Yes
Demographics	Yes
Mean monthly actual consumption	1519.04 kWh
Average monthly bill	151.52 €
Consumption groups	Group, Interventions (Smart meter, Technical support)

EBO's proposed interventions were the combination of, (a) a smart meter installation, and (b) the provision of technical support. EBO used a smart meter in order to enhance the energy savings and the technical support EE intervention included technical inspections and suggestions for equipment or insulation upgrades, etc.

We observed that the actual consumption and the monthly bill charged decreased in 2014 when the main interventions were initially implemented. However, since then, there has been a gradual increase in these two parameters and this is possibly related to a decrease in the average daily temperature, and therefore an increase in heating degree days.

Furthermore, customers who received technical support were slightly more than half the size of the sample (51.4%). In order to comprehend the efficiency of the proposed intervention in more depth, a normalization technique was executed regarding actual consumption per heating degree days. Those who have received technical support seemed to consume more energy than those who did not, 1522 compared to 1515 kWh/month, respectively.

Statistically speaking, there was a difference in actual consumption between those who received technical support and those who did not. The difference was not statistically significant (sig = 0.642). On the other hand, there was a small difference in normalized actual consumption between those who received technical support and those who did not (15.20 compared to 14.96 kWh, respectively). The difference was not statistically significant (sig = 0.498). Consequently, it was concluded that those who received technical support consumed more energy than those who did not. The achievement of the intervention was that the amount of energy consumed by those who received technical support met the level of those who did not receive it.

3.7. Enercoop—France

Enercoop is a 100% renewable and cooperative electricity supplier which contracts directly with producers. It sources renewable energy directly from producers and injects it into the common transmission and distribution network. The cooperative was born from the will of six associations and cooperatives to create an alternative supplier of 100% renewable energy. They chose a Cooperative Society of Collective Interest structure, which gives the partners an important place in governance, by dedicating a position to them within the Board of Directors [10].

The proposed intervention, "Dr. Watt", was a package of measures contained in an online tool. It included an offline training course to help consumers make a self-diagnosis of their specific electricity consumption, as well as an online manual regarding energy savings. The highlights of Enercoop's dataset are presented in Table 9.

Table 9. Highlights of Enercoop's dataset.

Period of measurements	01/2015–10/2018
Number of measurements	1,204,093
Interventions	2 (SMI and Dr. Watt)
Contract types	2
Production data	Yes
Meteorological data	Yes
Mean monthly actual consumption	350 kWh
Consumption groups	Members, Meteorological region, Contract type, Interventions (Smart meter, Technical support)

3.7.1. Energy Production

There was a significant increase in energy production (hydro and wind) since 2015, from an average of 1,333,475 to an average of 5,255,914 kWh (a 400% increase) as seen in Figure 6.

There was also a statistically significant difference (sig = 0.000) in energy production between the two types of energy generators (hydro and wind). Hydro production yielded an average energy production of 3.4 GWh and wind production yielded an average of 0.2 GWh.

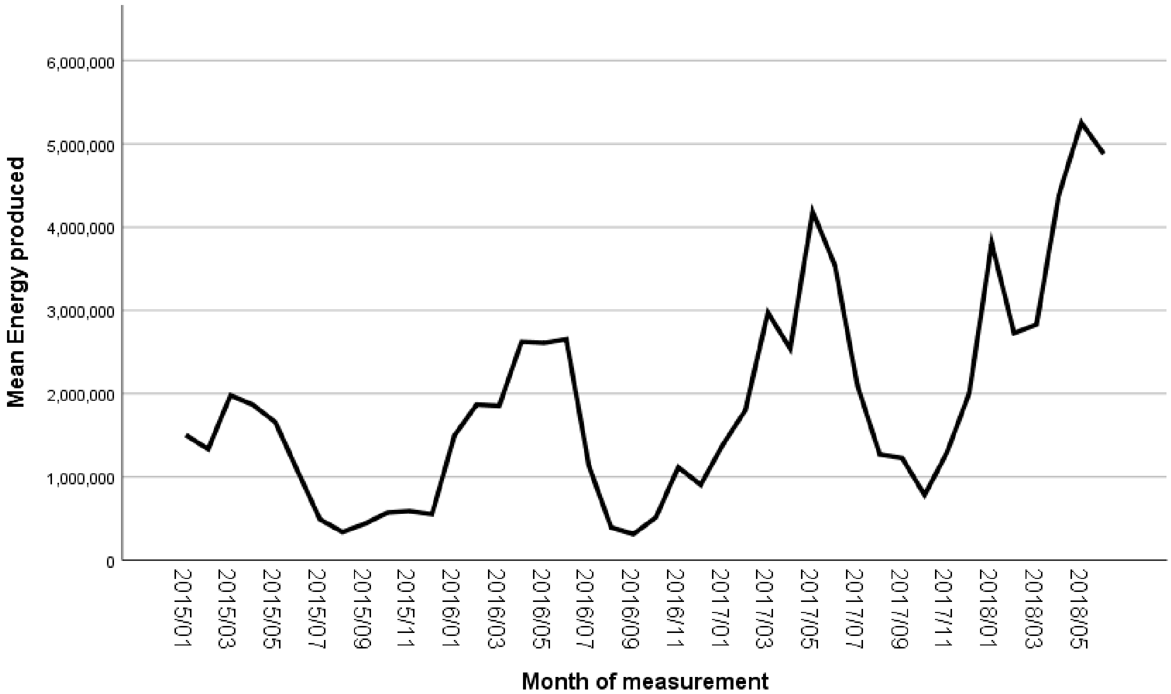

Figure 6. Mean monthly energy produced for the period examined.

3.7.2. Energy Consumption

For our analysis, a new variable named total consumption was created, which was the sum of the actual consumption, cooking, and electricity produced variables.

Customers were classified based on whether they were members of the cooperative or not (53.3% of the customers were not members of the cooperative and the remaining 47.7% were). There was a statistically significant difference (sig = 0.000) for total consumption between the members and non-members of Enercoop. Members of Enercoop consumed less energy (339 compared to 359 kWh for non-members) which translated to 8 $kgCO_2$ per customer.

In addition, as for the first intervention, and based on whether the customers were members or not, 99.7% of non-members and 98.6% of members did not use "Dr. Watt"; i.e., only 0.3% of non-members and 1.4% of members used "Dr. Watt".

We found a statistically significant difference (sig = 0.000) in total consumption between those who took part in the "Dr. Watt" program and those who did not take part. The customers who took part in the "Dr. Watt" program consumed on average 45 kWh less energy (305 kWh compared to 350 kWh for those who did not take part) which translated to almost 35 $kgCO_2$ per customer.

Regarding the second intervention (SMI), 24.5% of the total number of customers took part in 2018 while only 1% took part in 2015. There is a statistically significant difference (sig = 0.000) in total consumption between those who had installed smart metering and those who had not. The customers who had installed smart metering consumed on average 90 kWh less energy than those who had not (267 kWh compared to 362 kWh).

4. Discussion and Conclusions

Collecting REScoops data and examining the energy consumption of their members was a highly complex task, but one which was nonetheless required in order to assess the impact of their EE interventions. Such interventions are key for motivating alterations in the energy consumption behavior of European citizens in order to achieve the much coveted near zero emissions targets. REScoop Plus organizes the data gathering efforts of REScoops across Europe, and provides a methodology for assessing the usefulness of any given EE intervention.

In this paper, we presented the exact steps of the REScoop Plus data gathering process; the main pillars of the common data format (set after systematic research and a deliberation process); and our plan for, and the outcomes of, the statistical analysis executed. The core aim of this work was to statistically evaluate: (a) the impacts of proposed energy efficiency (EE) interventions in terms of energy consumption decrease; and (b) underline the most effective interventions in a recommendations toolkit. A range of summarized results is presented below.

Energy usage data collection, its sharing, and its 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) data. However, the data collected often come in different formats and time granularity.

The collection of credible demographic data, in particular (although hard to obtain due to privacy legislation), was crucial for some analyses as normalizations had to be executed in order to comprehend the results in depth. It is imperative to obtain access to these data, even in the form of REScoop wide average values.

Overcoming these challenges, TUC (Technical University of Crete) managed to collect and analyse substantial datasets from seven (7) different REScoops.

One of the important conclusions of our analysis is that there was a noticeable difference in actual consumption before and after implementation of the EE proposed interventions for the majority of the cooperatives, and that this can be converted into a tnCO_2 equivalent for each intervention. In addition, a difference between actual consumption under different tariff types was observed in every cooperative that implemented such an intervention. Furthermore, customers with EnergieID consumed less electricity (2023 kWh compared to 2193 for those with no EnergieID) which translated to almost 70 kgCO_2 per customer. Additionally, those who received technical support seemed to consume more energy than those who did not. Last but not least, the customers who took part in the "Dr Watt" program consumed on average 45 kWh less energy.

Consequently, implementing successful EE interventions of various types, such as technical support, special tariffs, energy generation schemes, and installing smart meters, leads to substantial energy reductions and also reduces the environmental footprint of the country where the cooperative is located.

As indicated from the results of the initial analysis conducted, the majority of EE interventions already applied by the REScoops, were quite effective in inducing more efficient energy consumption behavior, achieving more than 20% reductions. Importantly, for the cases where data were available, results indicated that becoming a REScoop member leads to "greener" customer behavior, as can be seen in Table 10.

Table 10 is an indicative tool for evaluating each proposed intervention and identifying the optimal ones. Smart metering installations indicated the highest energy reduction percentages, from 9% to almost 30%. This intervention seems to better enhance the perception and awareness of customers regarding energy consumption, as it offers the ability to track, in real-time, how much energy the customers consume. Two other techniques that showed energy reductions, of more than 10%, were the generation and empowering actions implemented by Som Energia. Some techniques which seemed to need more efficient design, planning and preparation, in order to be more effective, were the technical support by EBO, EnergieID by Ecopower, and the EE leaflets which were distributed by Som Energia. Regarding future recommendations, the research team proposes that the cooperatives continue gathering these types of data, use a specific data collection form and possibly re-evaluate the efficiency of their proposed interventions, using the results of this paper.

Table 10. The effectiveness of the proposed interventions.

REScoop	SEV—Italy		Coopérnico—Portugal	ENOSTRA—Italy	Som Energia—Spain	Ecopower—Belgium	EBO—Denmark	Enercoop—France
	Best Practice 1	Best Practice 2						
Period of measurements	09/2005–08/2018	09/2002–06/2018	06/2015–06/2018	08/2017–07/2018 09/2017–08/2018	01/2015–08/2018	2011–2016	05/2012–08/2018	01/2015–10/2018
Number of measurements	156	150	9441	3462 (304 customers)	862,886	194,028	25,369 (600 customers)	1,204,093
Smart meter installation (1)	v (**)	v (**)	x	x	v	x	v	v
Special tariffs (2)	x	x	v	v	v	x	x	x
EE leaflets (3)	x	x	x	x	v	v	x	x
Generation action (4)	x	x	x	x	v	x	x	x
Empowering action (5)	x	x	x	x	v	x	x	x
EnergieID (6)	x	x	x	x	x	v	x	x
Technical support (7)	x	x	x	x	x	x	v	x
Dr. Watt (8)	x	x	x	x	x	x	x	v
Energy consumption reduction	(1) 27.8%	(1) 17.6%	*	*	(1) 9%; (4) 25%; (5) 28%; (7) 1%	(6) 8.5%; (3) 30%	*	(1) 26%; (8) 13%

(*) It was not possible to compute reductions due to the inadequacy of the data; (**) combined with hydraulic balance of optimal temperature.

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