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Jérémy Wambecke, Georges-Pierre Bonneau, Renaud Blanch, Romain Vergne. What if we use the "What if" Approach for Eco-Feedback? Designing an Electricity Consumption Analysis for Layman Users. EnvirVis 2018 - Workshop on Visualisation in Environmental Sciences, Jun 2018, Brno, Czech Republic. pp.1-8, 2018, <https://diglib.eg.org/handle/10.2312/envirvis20181140>. <10.2312/envirvis.20181140>. <hal-01813283>

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Workshop on Visualisation in Environmental Sciences (EnvirVis) (2018)
R. Bujack and K. Rink and D. Zeckzer (Editors)

What if we use the "What if" Approach for Eco-Feedback? Designing an Electricity Consumption Analysis for Layman Users

J. Wambecke[1,2], G. P. Bonneau[1], R. Blanch[2], R. Vergne[1]

[1]Univ. Grenoble Alpes, CNRS, Inria, Grenoble INP, LJK, 38000 Grenoble, France
[2]Univ. Grenoble Alpes, LIG, F-38000 Grenoble France

Abstract

Many households share the objective of reducing electricity consumption for either economic or ecological motivations. Eco-feedback technologies support this objective by providing users with a visualization of their consumption. However as pointed out by several studies, users encounter difficulties in finding concrete actions to reduce their consumption. To overcome this limitation, we introduce in this paper Activelec, a system based on the visualization and interaction with user's behavior rather than raw consumption data. The user's behavior is modeled as the set of actions modifying the state of appliances over time. A key novelty of our solution is its focus on the What if *approach applied to eco-feedback. Users can analyze and experiment scenarios by selecting and modifying their usage of electrical appliances over time and visualize the impact on the consumption. We conduct two user studies that evaluate the usability of Activelec and the relevance of the* What if *approach for electricity consumption. Our results show that users understand the interaction paradigm and can easily find relevant modifications in their usage of appliances. Moreover participants judge these changes of behavior would require little effort to be adopted. Therefore our work opens new perspectives on using the* What if *approach in the context of eco-feedback technology.*

Keywords: (ACM 2012 CCS) Visualization systems and tools, Visualization design and evaluation methods, Empirical studies in visualization

1. Introduction

Reducing energy consumption is a major concern for many households. They either want to lower their energy costs and/or are motivated by environmental concerns such as the limitation of CO_2 emission. In this paper we focus on domestic electricity, which is an important share of household energy consumption. Thanks to the development of sensors such as smart plugs, households can easily access and record their electricity consumption over time. Eco-feedback technologies show a visualization of their consumption to users with the aim of decreasing it. In this domain many solutions have been designed, either commercial systems or research prototypes. One of the main limitations of eco-feedback tools lies in the difficulty for users to find concrete actions to save energy. Several systems tackle this issue by providing context to the visualization and/or ways to interact with the data [CRJ12, ELK*13]. However, interactivity is often limited and does not help users to find relevant modifications in the usage of appliances. As an example few systems provide the ability to visualize and manipulate usages of appliances along with raw consumption data.

In this paper we introduce Activelec, a visualization system that allows users to analyze and interact with their electricity consumption data. The design rationale takes into account previous findings and limitations of eco-feedback technologies, since the design is known to strongly influence users' ability to save energy [PFL*10]. The novelty of Activelec is the introduction of the *What if* approach applied to eco-feedback. Herein users can test scenarios in which they modify the usage of appliances over time and then evaluate the impact of these changes on the consumption. Our solution is based on a data model that represents the user's behavior as a set of actions modifying the state of appliances over time. To assess both the usability of the system and the relevance of the *What if* approach in the context of eco-feedback, we conduct two user studies based on real consumption data. Results show that users can find relevant and efficient appliance usage modifications, thereby validating the use of the *What if* approach for household electricity consumption feedback. To summarize we present the following contributions :

- The design rationale for Activelec that justifies the use of the *What if* approach in the context of eco-feedback, and especially the data model designed for this (Section 3).
- The Activelec system in itself, which allows to analyze and test scenarios on consumption data (Section 4).
- Two lab studies to assess the usability of the system and the relevance of the *What if* approach (Sections 5 and 6).

Finally our paper opens new perspectives on the *What if* approach in the context of eco-feedback discussed in Section 7.

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2. Related Work

2.1. Eco-feedback

Eco-feedback technology aims at presenting to users a visualization of their energy consumption in order to decrease it. Studies have proven the efficiency of eco-feedback in reducing energy consumption from 5 to 13% [Dar06]. Even if there is no definitive explanations for this efficiency, Buchanan *et al.* [BRA14] suggests one main reason. Users learn about the consumption of appliances, the link with their behavior and the actions that can be applied to the appliances to save energy. However, many limitations that impact the effects of eco-feedback have been pointed out in the forementioned surveys. The main bias in the design of eco-feedback systems is the assumption that visualizing energy consumption will directly lead to savings [Str11]. Such systems often lack interaction, reducing it to exploration of raw consumption data. Moreover, users encounter difficulties to come out with daily concrete actions that can be applied to reduce consumption [Bar15, ELK*13, Str11].

Several works focus on the design and evaluation of visualization systems for electricity consumption. Erickson *et al.* [ELK*13] developed the Dubuque Electricity Portal, a system allowing users to visualize their electricity consumption via an online portal. The contribution of this work is not the system itself, which presents a classical design. Rather it is the long term study with a large amount of participants, providing findings on eco-feebdack usage. We can also cite serious games dedicated to electricity consumption. This is the case of *PowerHouse* [BTK06] and *PowerAgent* [GKB10]. Both games are designed to acquire some knowledge about electricity consumption in order to decrease it. They are not focused on visualization but are similar to our approach, since the users can test a given behavior and obtain a feedback on it.

2.2. The *What if* Approach

The *What if* approach is usually implemented for the analysis of event based systems whose outcome depends on multiple complex factors, such as financial systems or large distributed systems. For example, Tarik *et al.* [TBV*13] developed WISE, a language designed to use the *What if* approach in the context of content distribution networks. This system targets expert users, and is based on a language implementation of the *What if* approach. In comparison, our system targets non-expert users and is based on interaction. Badam *et al.* [BZS*16] presented TimeFork, an interactive prediction technique for time series. The system allows users to interact with and guide multiple computational models predicting the future of multivariate time series, and thereby to test *What if* scenarios. In comparison, our system does not need computational models predicting the future. Users can experiment *What if* scenarios by analyzing and changing past values through interactive selection and modification of appliances states.

Costanza *et al.* [CRJ12] presented *Figure Energy*, a system based on the visualization of household electricity consumption. They provide users with the ability to manually annotate their activities and to apply *What if* scenarios by removing them. The important difference with our system is that modifications are limited to removing user activities. More importantly the user activities are only removed in another view which does not impact the temporal visualization. In comparison our system allows temporal selection of usages and modifications such as changing appliances states and duration of usage. In their visualization design method, Goodwin *et al.* [GDJ*13] detailed *Demand Horizon*, a prototype that allows the consumption of appliances to be modified by directly sculpting the raw data. If their studies gave promising results, it is worth noting that the system was designed for energy analysts and modelers to elaborate scenarios directly on consumption data of multiple households. In contrast, our system is designed for non-expert users without any assumption on their knowledge in energy consumption.

3. Design Rationale

3.1. System Description

During studies about eco-feedback systems, users often encounter difficulties to find concrete behavior changes to reduce their consumption [Str11, Bar15, ELK*13]. Our system is designed to tackle this problem, since users visualize, interact and modify their usage of appliances instead of visualizing raw consumption data. First, users explore their data by visualizing their usage of appliances linked to their consumption. Then, they select actions on appliances via criteria, followed by a modification of the actions that have been selected. Once the modification is applied, the visualization is updated in a way that allows users to evaluate the impact of their scenario on the consumption. This interaction loop motivates users to engage their data by manipulating concrete actions on appliances, *e.g.* ecological washing versus normal washing for a dishwasher. Our system is a dashboard, *i.e.* a classical computer software that provides historical views of the data, allowing patterns and trends to be recognized [Str11, Bar15]. Hence it relates data to behavior using classical information visualization methods.

3.2. Strengths of the *What if*

The appliances and especially their consumption per usage vary among households. This implies that a modification in the usage of an appliance can lead to different gains. As an example, switching off the lights can lead to high or low gains depending on the efficiency of the bulbs. Thus users need to have precise information about the outcome of behavior modifications instead of generic advices such as “switch off the lights”. Another strength of our approach is the ability to test repeated subtle modifications over time. A given change (*e.g.* boiling only the needed quantity of water in a kettle) can seem negligible but may lead to substantial gains if repeated every day. By allowing users to visualize the accumulated gain over time they become aware of the relevance of such modifications.

The *What if* approach allows users to assess the ratio between gain and effort required to apply their modification into their everyday actions. It seems trivial to gain energy by reducing the usage of appliances, yet in practice, this is strongly dependent on external factors constraining our use of household devices. For example savings that could be achieved on the washing machine depend on the number and the ages of people in the household, as well as on temporal factors (*e.g.* possible day and hour of usage). It also depends on personal factors such as users' motivation. These factors,

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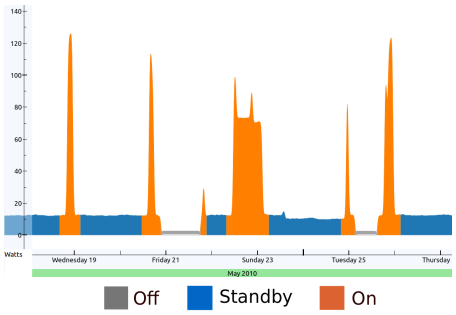

Figure 1: *Data related to a computer with three states. Each state is associated to a unique color, which is used to depict its time intervals on the consumption curve of the appliance.*

often neglected in eco-feedback [PFL*10], cannot be known by the system. This supports the use of the *What if* approach which allows these factors to be analyzed individually.

The *What if* approach can also counteract another limitation of eco-feedback systems, which is the non-negotiability of everyday practices [Str11, PFL*10]. In other terms it means that some appliances usages cannot be removed due to external constraints (*e.g.* social constraints). For example, to stop using the washing machine is not conceivable since people want clean clothes. Our system allows usages to be both removed or modified. For example, users can switch the temperature of the washing machine from warm to cold, which can lead to a substantial gain.

3.3. Data Model

We designed a data model that decomposes appliances data between consumption data and user's actions data. In this model, the input is disaggregated energy data where each appliance is associated to a temporal dataset. Consumption data represents the evolution of the instantaneous electric power of the appliances, and is measured directly or simulated when a modification is applied. Appliances are associated to states over time (*e.g. Off*, *Standby* and *On* for a Computer). At a given point in time the state of an appliance thus depends on the action of the user. Therefore the states of the appliances allow to express the relationship between consumption data and users' actions. We define an *instance* of a state as the time span during which the appliance remains in this state. Instances hence encode the evolution of the state of the appliance over time. The instances are automatically extracted in the system based on thresholds on instantaneous power and average consumption over time. Figure 1 shows an example of evolution over time of computer data according to this model.

4. System Design

4.1. User Interface

Our system is built on two modes: *Appliances mode* and *Instances mode*. *Appliances mode* (Figure 2) displays the consumption of all appliances on the same plot, allowing users to explore and compare them. This mode gives to users an overview of the consumptions of household appliances. From this mode, users can switch to *Instances mode* (Figure 3) to focus on a given appliance. *Instances mode* displays the consumption data and the usage of a single appliance and implements the *What if* approach. The units of energy such as kWh are often considered abstract by users and need to be converted into meaningful information [Str11]. Hence the amounts of energy consumed by appliances, contained in selections or saved by modifications are expressed in terms of cost aside with the kWh. Our system is also able to express the energy in environmental units, such as pounds of emitted CO_2, which makes sense for users with environmental motivation [Bar15].

4.2. Visualization

To display the evolution of the consumption over time, we chose to use line charts, since it is a well known metaphor for continuous temporal data. They are also well suited for fluid interactions like continuous pan and zoom. Consumption curves are rendered and filtered in a screen-dependent manner [BM04]. That way, unlike most eco-feedback systems that aggregate the data at a fixed scale, the curves can be visualized at any zoom level and are always smooth and coherent. In *Instances mode* the curve is colored according to the instances of the appliance. More precisely, the part below the curve is filled with the color of the current state. By using this representation, users can visualize the consumption along with the usage of the appliance. A multi-hue color scheme from *ColorBrewer* [Bre03] is used to assign colors to appliances and states.

4.3. Selection

In *Instances mode*, instances can be selected to obtain information on the usages or to modify them. The first way to create a selection is to do it directly onto the visualization by clicking on the instances. It allows users to select particular instances that could not be selected with temporal criteria or to test a modification on a few instances. The second way to select instances is through the definition of criteria on their properties. In its current implementation the system provides the possibility to select instances according to their state, duration, weekday, day hour and by frequency. For example, for a given appliance (*e.g.* a computer) users can select all the periods of *Standby* whose length is greater than one hour. It is also possible to combine criteria, such as selecting only one out of three instances from this selection on the computer. Once a criteria is modified, the set of selected instances is updated in real time, and these instances are highlighted on the curve. Defining criteria to select instances extends the exploration step, since users can explore the space of criteria with real time feedback. It also allows to generalize a pattern found during the exploration step, hence allowing habits to be easily visualized and modified.

4.4. Modification

After the selection of instances, the next step in the loop of the *What if* is their modification. Our system provides two types of modifications. The first one is changing the state of the instances, which is related to removing a usage of the appliance or modifying the way the appliance is used. For example, it is possible for users to switch the state of instances of a washing machine from warm washing to cold washing. The second kind of modification is limiting the time

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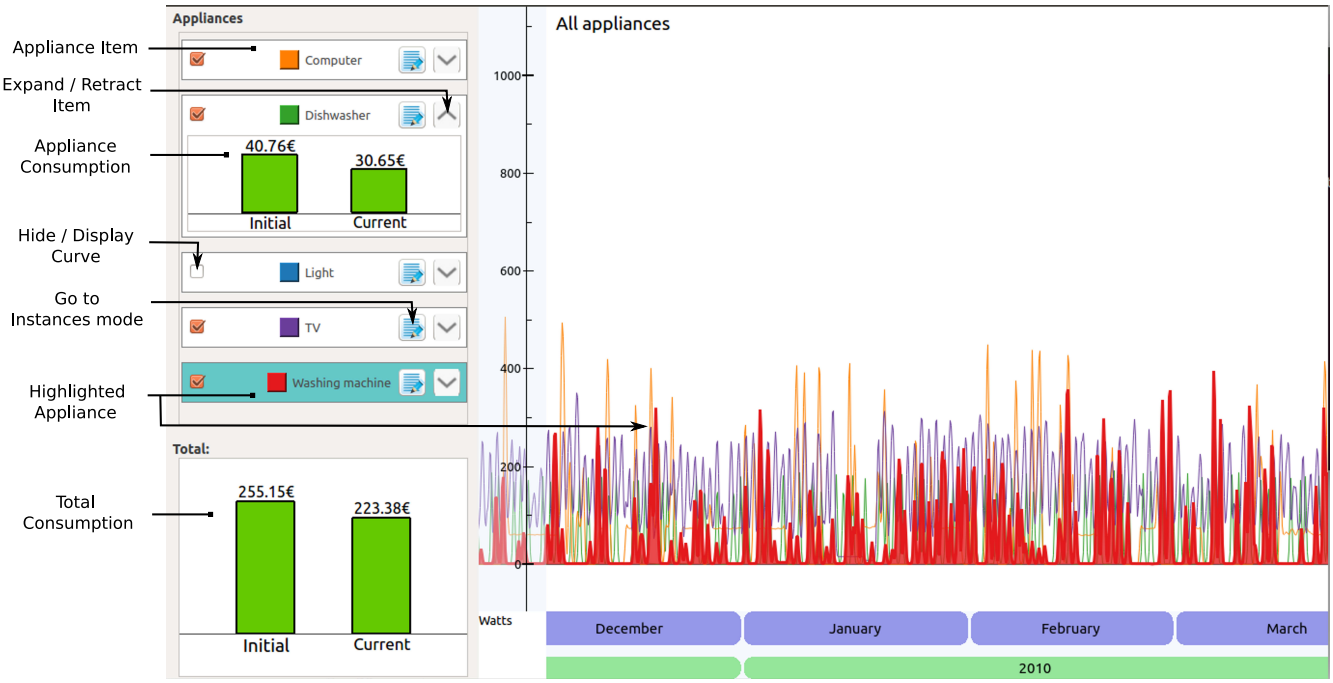

Figure 2: *Interface of the Appliances mode. Five appliances are displayed: a computer (orange), a dishwasher (green), a light (blue), a TV (purple) and a washing machine (red). The washing machine has been highlighted by the user, and the item of the dishwasher has been extended to display its consumption values.*

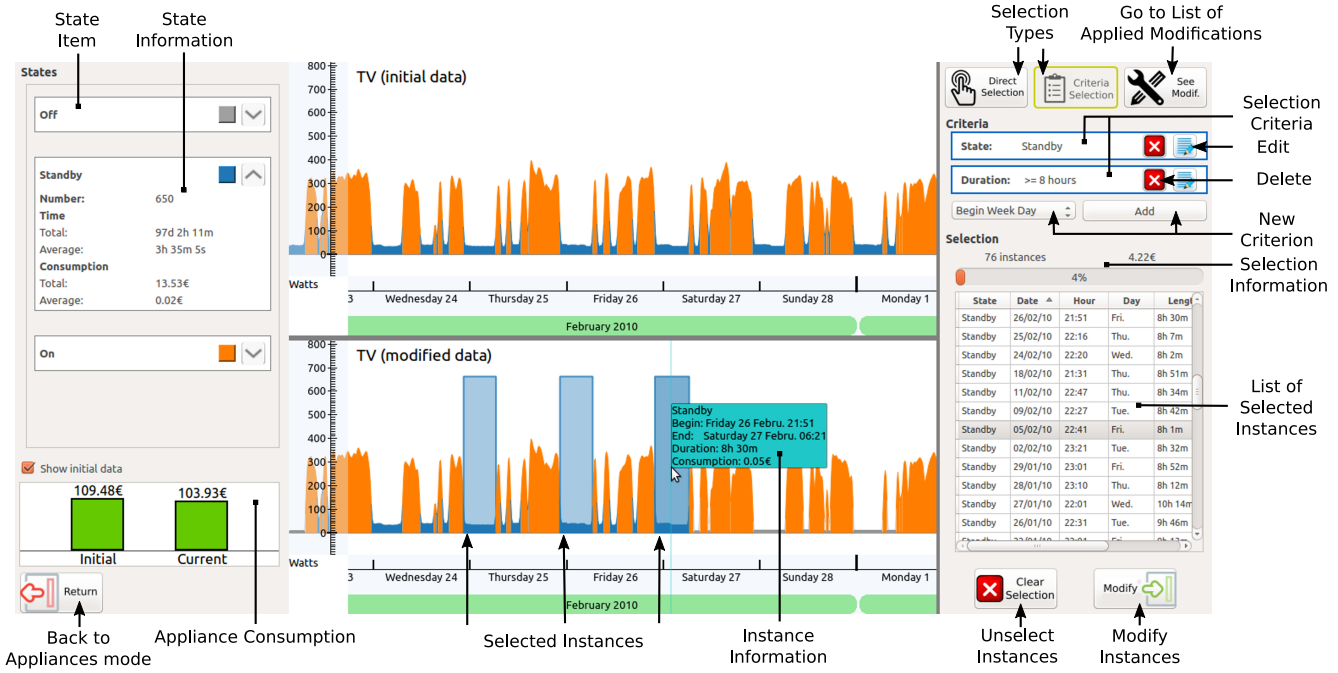

Figure 3: *Interface of the Instances mode. A TV has been chosen by the user, whose states are Usage (orange), Standby (blue) and Off (grey). At the right, we can see that the user has selected all instances of Standby lasting more than 8 hours via the definition of two criteria. Three of these instances are visible on the visualization.*

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of the instances either to a given duration or after a given hour in the day. The extra part, *i.e.* after the limit, is removed and replaced by *Off*. For example, users can limit all instances of *Standby* of a TV to 2 hours, or stop them after 11 p.m. When a modification is applied, the visualization is updated accordingly by computing new data. For each applied modification, a widget in the list of applied modifications to the right gives information about its selection, its type of modification and more importantly its gain or lost value. Users can do as many modifications as they want, which are added to the list to be compared, modified or deleted.

5. Usability Study

We conducted a first user study to evaluate the usability of Activelec and especially to assess if users can easily find relevant modifications in the usage of appliances. To do so, we designed a controlled experiment where participants used the same dataset, coming from real appliances.

5.1. Method

13 users (11 males, 2 females) participated in the study. The participants were recruited in the faculty, and were distributed among 7 PhD students, 1 post-doctoral student, 4 engineers and 1 professor. Among these 13 participants, 11 had no knowledge of visualization tools. Only half of them (7) had energy knowledge, *i.e.* they could define electrical power and energy. All participants were motivated in saving energy, but 4 of them said that they did not want to put too much effort to change their behavior. One participant did not follow the instructions, thus we did not consider his results. For this study we used actual data from the *Household Electricity Survey* [Dep16]. We selected six months of data from ten common appliances. We manually defined the states of the appliances so that our tool could extract the instances from consumption data.

The experiment was preceded by a learning phase of approximatively 25 minutes. The first step of this phase was the explanation of the tool by one experimenter. As a second step of the training phase, the participant had to reproduce two modifications that were given by the experimenter, on two different appliances. To conclude this phase the author asked if the participant had additional questions before starting the task. For the task we asked participants to find actions which save energy by using the tool as if they were at home with their own data. We did not enforce saving objectives so that participants can freely use the system. To evaluate the relation between savings induced by the modification and the effort to apply it in the home, we used a subjective measure rated by the participants for each modification they did in the system. It evaluates how much a modification in the usage of an appliance is seen as difficult for participants to apply in their home. We asked participants to rate this effort for each modification on a psychometric scale from 1 (no effort) to 5 (maximum effort).

5.2. Results

Table 1 presents quantitative results from the task. For each appliance, the mean gain is the average for all participants of the ratio in percentage between the gain realized by the participant and the original consumption. Analogously the mean effort for an appliance is the average effort rated by the participants for the modifications that were applied to this appliance. On average, participants saved 36.73% (σ = 12.53) of the total energy consumption and modified 6.75 appliances out of 10 (σ = 1.06) with an effort of 1.48 (σ = 0.39). The most consuming appliances such as the heater, the computer or the TV received higher efforts from the participants. In contrast the lowest consuming appliance were the subject of few modifications. All users managed to successfully use the system regardless of their knowledge about energy or visualization. Furthermore once participants decided to test a modification they could do so in less than one minute, and often in only a few seconds. All participants spent approximately 10 minutes using the tool until they were satisfied by their modifications.

Once participants finished the task, they filled a questionnaire based on a Likert scale from 1 (*I totally disagree*) to 5 (*I totally agree*). This questionnaire was designed to collect participants'

Appliance	Total Cons.	Mean Gain (%)	Mean effort	Nb. modif. (Nb. diff.)
TV	175.0	32.9%	1.7	15 (7)
Heater	136.0	22.7%	1.8	10 (4)
Computer	116.5	48.8%	1.7	11 (8)
Dishwasher	65.5	54.2%	1.3	12 (7)
Washing Machine	47.5	44.0%	1.3	9 (4)
Tumble Dryer	36.0	50.1%	1.3	12 (3)
Kettle	30.0	29.7%	1.0	6 (5)
Game Console	17.5	22.0%	1.3	7 (4)
Toaster	4.7	0.0%	NA	0 (0)
Light	3.7	2.3%	1.0	2 (2)

Table 1: *Total consumption in money (euros), mean gain, mean rated effort, and total number of modifications for all participants (with number of different modifications) for each appliance used in the task.*

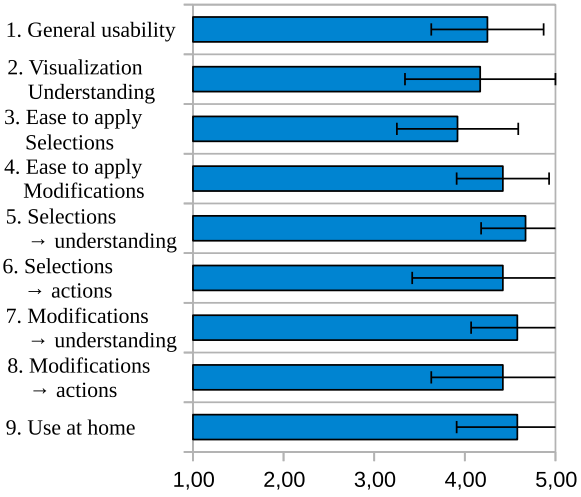

Figure 4: *Rates from final interview. "→ understanding" means helps in understanding consumption and behavior and "→ actions" means helps to find relevant actions to save energy*

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feelings about the system. Averaged rates and standard deviations of the questions are shown in Figure 4. Results show that the system was clearly understood by participants and easy to use. We also asked to participants which functionalities they had appreciated/disliked the most. Among them, the interaction was positively mentioned by 7 participants, the usefulness of a cost feedback by 6 participants, and the design of the visualization, including the choice of the colors by 5 participants. As negative points, potential improvements for the user interface were mentioned by 4 participants. For example, participants would have liked more details about the states of the appliances, such as their relative consumptions. These suggestions have been integrated in the user interface before the second study described in section 6.

5.3. Discussion

The main objective of this first study was to assess the usability of Activelec and especially the *What if* approach applied to eco-feedback. Whereas participants did not use their own data during the study, they could understand the consumption and link it with the usage of appliances thanks to the tool. Moreover, this understanding was reinforced by the application of selections, especially with criteria. Finally, modifications in the usage of the appliances were easily applied by the participants. Indeed results show that participants found several different modifications on the appliances in a short time period. One of the problems that users face when using eco-feedback systems is finding the relevant appliances to save energy on [Str11]. Results of the study show that participants solved this problem with the help of our system. This is shown by the choices to modify high consuming appliances or appliances on which the effort to put on are seen as low by the user. Moreover, the low average efforts rated by the users suggest that they were able to find actions that are judged easy to apply in reality.

6. Application Study

In addition to the user study presented in the previous section, we conducted another study aimed to assess how people use the tool with their own data. Our hypothesis is that users will be more involved in the step of data analysis. We also suppose that they will find relevant modifications that comply with their behavior in order to save energy.

6.1. Method

We recruited two PhD students that had previously recorded their consumption of electrical appliances. The recording took place in a dedicated smart home where participants lived during one month. The corresponding datasets are made available online by their authors [CLRLC17, LLR*17]. The study was conducted after the end of the recording period, when participants no longer lived in the smart home. Both participants said that they were motivated in saving electricity. One participant could define power and energy, but participants were not experts in electricity consumption. They were not specialists in information visualization. The states of the appliances in the datasets were manually identified and calibrated by the authors. Then the instances of the appliances were automatically extracted in our system. Appliances and states used in the study are presented in Table 2. For this study we used the same protocol as in the previous one, *i.e.* the same learning phase was followed by the task in which participants managed to find modifications that save energy.

Participant 1	**Participant 2**
Computer: *On*, *Standby*	Oven: *Low*, *Medium*, *High*
Living Room TV: *On*, *Standby*	Dishwasher: *Normal Washing*, *Eco Washing*
Bedroom TV: *On*, *Standby*	Washing Machine: *Normal Washing*, *Eco Washing*
Global Lighting: *On*	
Cooktop: *Low*, *Medium*, *High*	
Water Heater: *On*	

Table 2: *Appliances used during the second study with their states. The three last appliances were common to both participants.*

6.2. Results

Participant 1 applied three modifications on the appliances and saved 7.47% of the total amount of energy, with an average of 1.67 as estimated effort to apply the modifications. Participant 2 applied six modifications and saved 31.54% of the total amount of energy, with an estimated effort of 2 in average. Despite the fact that the set of appliances was different between participants, we can see that Participant 2 managed to save more energy by applying more modifications. The modifications were also rated with a higher average effort by this participant. From the gains, we can say that participants managed to save a considerable amount of energy even if the datasets do not exhibit high energy consumptions. Both participants spent approximately 15 minutes using the system.

Figure 5 shows the answers of the participants to the questionnaire about usability. We can see that both participants found Activelec easy to use. Results also indicate that the system was useful to understand the usage of appliances and their consumption, as well as to find actions to save energy. We can note that Participant 1 rated with a grade of 3 the two questions about the potential for selections to make data understandable and to find concrete actions to apply. Participant 2 gave the same rate for the same questions about the modifications. The explanation is that selections and modifications are used together to understand the data, as said by one participant. In the final interview, both participants said that they appreciated the visualization that allows for a detailed exploration at any time scale. As negative comments, participants only mentioned potential improvements for the interface. For example, one participant would have appreciated the consumption by month of the appliances to be displayed together with their total consumption.

6.3. Discussion

We observed that participants were more engaged in the data than in the previous study, as shown by the higher amount of time spent using the tool. This is explained by the fact that participants used their own data in this study as opposed to the previous study. They were able to relate the data to their habits. For example, they easily

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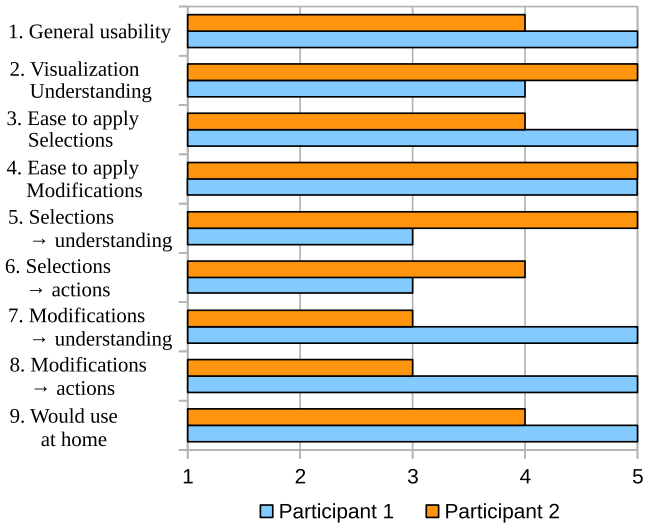

Figure 5: *Rates from final interview of the second study. "→ understanding" means helps in understanding consumption and behavior and "→ actions" means helps to find relevant actions to save energy.*

identified their everyday actions such as taking a shower or cooking via the states of respectively the water heater and the cooktop. They also identified abnormal electricity consumptions that could be removed to save energy. For example, one participant observed that the water heater was heating water during each afternoon, while it was not used. Thus this participant removed this usage and said that the water heater should be configured to avoid this consumption.

We also noted that participants applied modifications that we did not expect before the study. One participant limited the usage of the cooktop to 30 minutes since it was often left on after cooking. The other participant realized that one light was used to read during the day and its consumption was substantial. These modifications saved a significant amount of energy. This supports our hypothesis that users will be more involved in data analysis as well as find relevant modifications that fit with their behavior to save more energy, as presented in Section 3. Participants also wanted to test for modifications that are not currently possible. For example, one participant noted that two machine washings were done the same day. This participant would have liked to verify if one full machine washing is more efficient than two half-full ones.

7. Discussion and Implications

7.1. Limitations

A possible limitation of the *What if* approach is the requirement of user involvement, which is an inherent problem of eco-feedback dashboards [ELK*13]. To counter this limitation, Bartram [Bar15] suggests the use of ambient systems, whose feedback is spatially (close to the appliances) and timely (when using the appliance) appropriate. Using a dashboard with temporal visualizations is necessary for our approach especially for interaction. However, we could imagine an ambient display located near the appliances to recall the chosen modifications. This display could also provide information about the energy saved by modifying the appliance usage.

In a preprocessing step, our system extracts the instances of the appliances using empirical thresholds which requires manual tuning. More advanced algorithms could be used in the future to segment the input data automatically and more precisely. Also, when users modify the instance of an appliance by changing its state, we need to simulate new consumption data according to the new state. Currently this is done by copying the data associated to another instance of this state. In future works it would be interesting to incorporate more reliable simulations of state modifications. In addition the consumption of some appliances depends on external parameters that are not taken into account by our model. For instance the consumption of fridges directly depends on parameters such as room temperature. To overcome this problem, we could use physical simulations that take environmental parameters as input.

7.2. Perspectives

Field Study The studies that we conducted show that users were able to find modifications that fit to their behavior. However there still remains work to prove that the *What if* approach is suitable in a home context. Hence we would like to go further and deploy the system in households for an in situ experiment. While asserting a change in behavior requires a long-term study and is beyond our research domain, the first step would be a mid-term study, *e.g.* a couple of months. This additional study could bring information about how Activelec is used in a household context. Users will test *What if* scenarios that they would incorporate into their everyday habits. Then, they might come back to the tool to check their new consumption. Users could also try new modifications or refine their previous scenarios. For example they might want to save more energy or to put less effort to change their usage of appliances.

Integration in a Home Automation System We envision incorporating our tool in a home automation system such as AppsGate [CC16] where it could directly take the values of sensors as input. Users could test several modifications and define the preferred ones as rules that automatically apply on the appliances. For example a rule that automatically switches off the TV after 10 PM during weekdays could be generated from the appropriate modification. In a general smart home system, our tool could also benefit from other available data sources. For example users would relate the consumption of the heater to the external temperature, and lower the heater if the temperature is sufficiently high. Activelec could also be used for the analysis of other utilities such as water and natural gas. The system currently runs in a desktop environment but it can be adapted to a tablet with little effort. This would allow users to analyze their consumption everywhere in the home, especially near the appliances on which modifications are applied.

Suggestions The development of an automatic system that finds the best modifications for every user seems unreachable. Indeed, only inhabitants have the knowledge of how and why they use their appliances, and what is the effort required to change this usage. However it should be useful to suggest modifications that seem appropriate in terms of gain and estimated effort. For instance switch-

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ing to ecologic washing seems to require a reasonable effort. Suggesting selection criteria and modifications will also provide a first step to novice users, since they will directly have access to examples.

Additional "What if" Features For now, Activelec allows the modification of past data but the *What if* approach can also be used in other ways. We could imagine the extraction of a typical week in terms of appliances usage and consumption. For example, in a typical week inhabitants could always turn on the coffee machine in the morning, and watch the TV during two hours in the evening. Then this typical behavior could be modified by users, hence applying the *What if* approach on current data instead of past data. It would also be possible for users to create their behavior entirely from scratch. In this way the *What if* approach would be applied to hypothetic future data. Activelec currently targets the reduction of consumption and not the shift of consumption peaks. Since the units of energy are computed dynamically from watts our system could easily apply time based pricing. However the system should be modified to allow the visualization of energy prices over time and to shift usages of appliances.

8. Conclusion

In this paper we present a system for users to analyze, interact with and modify their electricity consumption data. In this system we model the appliances as having states over time, which are modified by users. Thanks to the *What if* approach, users can select and change the state of appliances over time. The visualization allows them to evaluate the impact of their modifications on the consumption. Users can then assess the ratio between energy saving (money saved) and the required efforts to apply these modifications in their behavior. Our studies have proven the usability of the system and the ability of the users to find modifications with a reasonable effort. This work opens new perspectives on applying the *What if* approach to the visualization of household electricity consumption and even personal visualization systems in general.

Acknowledgements

This work has been partially supported by the LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01) funded by the French program Investissement d'avenir.

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