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► **To cite this version:**

Gilles Guerassimoff, Johann Thomas. Enhance energy efficiency, technical and marketing tools to switch people habits in the long-term . 7th International Conference EEDAL 2013 Energy Efficiency in Domestic Appliances and Lighting, Sep 2013, Coimbra, Portugal. pp.ISBN : 978-92-79-38406-6. hal-01537906

HAL Id: hal-01537906

<https://hal.science/hal-01537906>

Submitted on 13 Jun 2017

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Enhance energy efficiency, technical and marketing tools to switch people habits in the long-term

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Abstract

Electricity consumer behaviors are known to be both hard to change and unstable. From this point of view a state of the art of smart-grid experiment and an overview of Home Energy Management Systems show that after a first phase of enthusiasm and energy efficient efforts, the moves cool down. Equipped people tend to take back their habits or to let the system run on its own, giving no more consideration to energy saving actions. Several cases even show a rebound effect, where people consume more energy that before the system was launch.

In order to keep people focused on their own energy efficiency behavior and help them to make the effects more long-lasting, the Grid-Teams project, held in 2012 in the city of Cannes, French Riviera, decided to focus on nudge marketing to assess whether these kind of services could enhance user's loyalty on efficiency habits.

By *nudge marketing*, we mean several tools to help users to understand and act. The experimentation helps them focus and to fully handle their own electrical impact. For this purpose, we metered forty households and built a complete Web user interface with several nudge services including a range of energy consumption, with two bounds; a higher level: the consumption as usual (CAU), and a target to reach: the goal. In the same time a genuine loyalty program called EcoTroksTM was also developed. This paper explains how this electricity consumption range, from CAU to *the goal*, is computed and how the associated loyalty program seems to be an efficient manner to keep people involved in the program.

Introduction

The ongoing research on Smart Grid's deployment and applications [1, 2, 3] promotes the energy management in residential dwelling [4, 5, 6]. The future integration of smart metering needs to set new tools to inform and educate the final user to new consumption modes in the housing. Indeed, for many families, energy management is not a particular priority as the energy price is not high enough to be a significant part of the household expense.

It is still important to find a way of informing the final user so as to put them in a central place to be able to use all the potential of the smart grids. The *demand response* process that will be possible in the residential sector with the appropriate technologies will need the active participation of the final user. So how can we change the end user behavior to become active and reactive in his energy consumption?

It is the aim of the Grid-Teams' project supported by the program "agir ensemble pour l'énergie" of the regional authorities for south east of France (Région PACA) and the French agency for environment and energy management (ADEME) and coordinated by the company Gridpocket. The project involves the following companies: Planete Oui, WIT, the city of Cannes (in the south of France) and research laboratories (the Centre for Applied Mathematics of Mines ParisTech and the Sociological Centre of Telecom ParisTech). This project has developed a specific tool to assess the families' consumption and help them in the energy management of their housing. The originality of the project is to encourage the families in their way of having a better energy management by creating some social and cultural incentives. To verify the veracity of the methodology, the project has conducted experimentation on 40 families during one year in the city of Cannes [7].

We will present in the first part of this paper the methodology that has been employed to assess the housing and the family's energy behavior. In a second part we will present the tools that have been developed and deployed on the experimental panel. Then in the last part we will present some results obtained with some families.

Methodology

The project presented here aims at explaining the families the way of they use energy in their housing. As soon as they will understand where they can act to reduce their consumption, then they will be able to plan actions to reduce their consumption.

To achieve such an objective, we have to propose these families some tools to assess their consumption and other methodologies to make them active in the reduction of their consumption. To be able to show the users their consumption's level and to give them bounds adjusted to their particular case (an upper bound and a lower one), it is necessary to know details about three aspects:

The first one is **the structure of the housing**; the second one is **the appliances employed in this housing** and the third one is **the behavior of the family** living in this housing regarding energy uses. When these three topics will be identified, we will be able to propose them a kind of instrument panel that will show them in real time their consumption and the corresponding level regarding their specific bounds.

For these three levels of information we have to focus on, detailed inputs are very difficult to obtain without a completed study for each housing. The project proposes to elaborate a simplified model that can be representative of each housing without having resort to detailed analysis. To provide such a tool, we have analyzed a panel of 40 housings to validate our methodology.

Structure characterization

First of all we have realized a dynamic thermal simulation of the housing to determine its thermal performance and its sensitivity to its environment [8, 9]. The aim of this simulation is to determine some key parameters to elaborate some criteria that can be reused for similar buildings. For example, in a flat, the numbers of neighbors or the structure of the building is of a high importance to evaluate the bounds of the energy consumption.

Here is a scheme of the model for a flat that has been modeled with Comfie/Pleiade software.

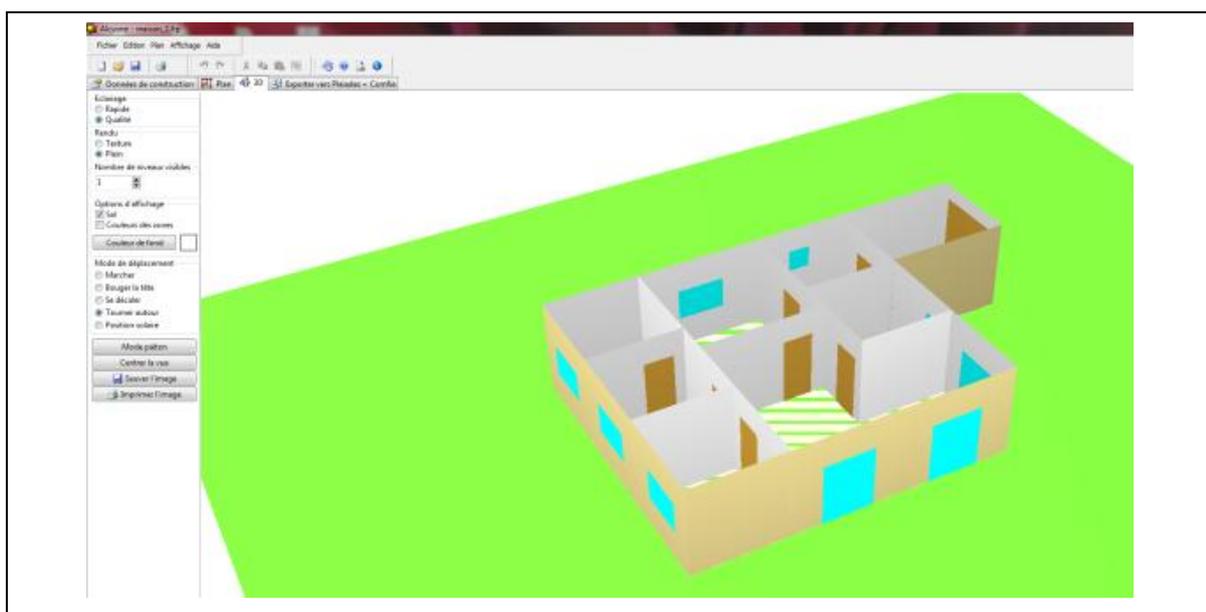


Figure 1 - Example of the housing representation in the dynamic thermal simulation tool.

With this simulation we obtain the need of the energy need of the building to maintain a given comfort temperature during an all year.

After that, the confrontation of these detailed simulations with a simplified thermal model for the building brings us to be able to identify the global thermal losses coefficient that can be identify to a category of building. This combination of the detailed way and a global way of calculus permits to elaborate some cursors to characterize similar buildings in the same range. The finality of this structure's building evaluation is to provide some cursors that can be adjusted with the results of a simplified survey.

Appliances characterization

The second phase is to inventory all the appliances in the housing and to assess the use of them by the families. It is difficult to quantify the reality of a specific use for an appliance. For example, how long do we use a kettle in a day? To achieve this inventory and the level of use of them, we have worked with the results of a European project (Remodece) [10, 11, 12] that has produced a big database of appliances load curves for several countries. Regarding the appliances, first of all different categories have been established to ensure a generalization of the methodology. Indeed, the numbers of appliances are too important and too diversified to have, for each family, and exhaustive count of them. And even it could have been possible, the quantification of their exact use is impossible to implement except with an energy metering for each of them that is not feasible. To compensate this lack of available information, a "brown" category including all appliances dealing with audio and video (TV, DVD player, video games, internet box...) has been created. A "white" category has also been created included all appliances we can find in the kitchen (Washing machine, oven, coffee machine...). The lightning, hot water, heating and cooling of the building are considered individually.

With these categories, two kinds of index have been determined. The first one is the level of equipment of the family. Based on a simplified survey regarding the kind and the number of appliances the family's got, the cursor can be move from a low equipped family to an over equipped family. The cursor will imply a level of power installed for appliance in the housing. The second one is also based on a simplified survey that evaluates the order of magnitude of the use of these appliances. This cursor can vary from a low use to an intensive use of these appliances. This level will determine a level of energy consumption in the housing. The combination of these two cursors gives a characterization of the family regarding their appliances uses in term of energy consumption and then it becomes possible to inform the family on its behavior.

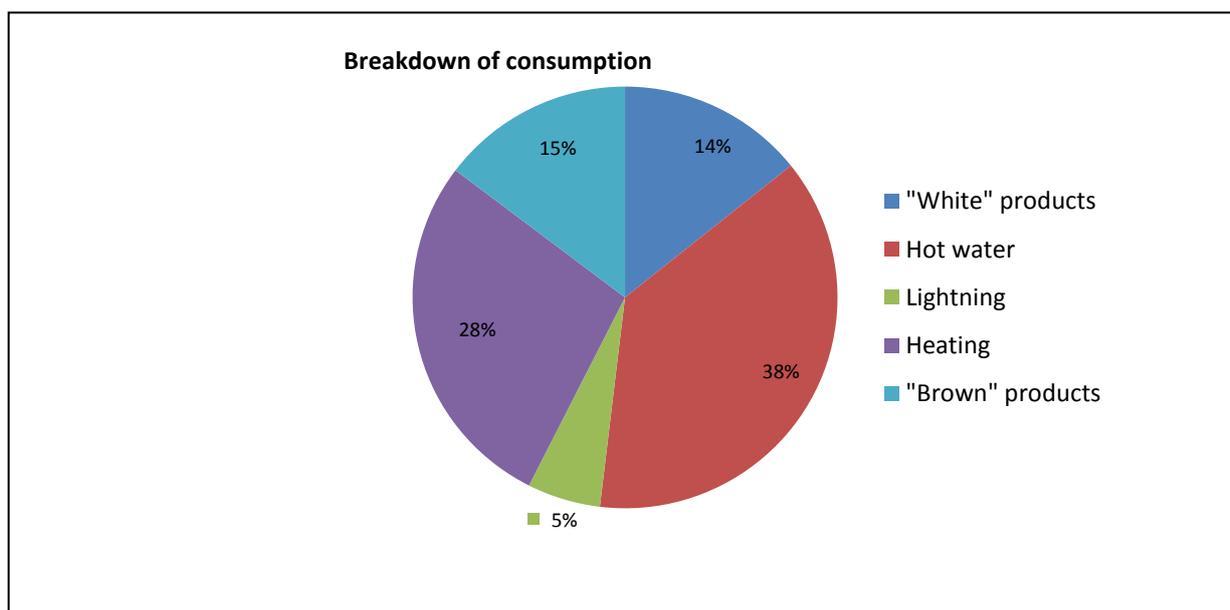


Figure 2 - Example of a breakdown of the consumption a of family provided bay our characterization

Behavior characterization

The last phase is to have an idea of the family behavior inside its housing. It is a very tricky task because this assessment can provide very significant differences in the results. To achieve such a goal, a sociologist team has realized detailed interview of the panel of families involved in the experiment. With these interviews, the sociologists have to identify the most pertinent characterization of a kind of family in term of its energy sensibility to be able to inform them about their uses and to orient them to a path of a more efficient way of their energy management [13, 14].

These interviews have to be match with their relative energy profiles (Building and appliances characterization) to provide an estimation of the differences we can observe between the theoretical energy needs regarding the structure of the housing and the real energy consumption realized. The second important point of this part of the analyses is to characterize the ability of the family to react to its own consumption and its capacity of reaction to these signals. The behavioral changes have to appear and also have to be sustained in a long term. To achieve with goal, the tools deployed in this project have to be well adapted for family that may not have any knowledge of energy topics. Some incentives have been included to strengthen such a goal. Indeed, one of the originality of this project is to add social incentive to the process of encouraging the families to a way of a better energy management of their housing. The goal is double; on the one hand is to encourage the family to make efforts on their energy consumption, on the other hand it is to develop some new social links as a consequence of their efforts. The incentive provides some useful gifts as bus ticket, low consumption light bulb, or social or cultural activities like concert places of tickets for local events.

The results of this behavior's characterizations have to be consolidate at the end of the project to assess its sustainability. The results of such a methodology can strengthen the effect of energy efficiency actions [15, 16].

Tool conception

To assess the characteristics of the buildings and to be able to provide the information in real time to the families, a smart meter has been installed in each housing of our panel. This smart meter is sending to a data center the power consumption of the housing each 50 watt modulation. These data provide to the system the detailed load curve of the family. Moreover, the temperature of the principal room of the housing is also sent to the data center. This temperature measure is very important to assess the comfort level and also give us precious information on the thermal behavior of the family. As the heating and cooling energy consumption can be the most important part in a building that do not correspond to the latest thermal regulation.

Regarding the results of the three characterizations describe previously, a web interface has been created to show the families their load curves and the bounds that correspond to their specific housing. A direct and secure connection for each family has been crated and they can interact by Email with a person that can answer to their interrogation. Moreover, the system can provide individually some advices after a rough analyze of their load curve to put them on the way of their energy management.

Web Interface development

The interface is the meeting point between technic and human. Therefore, it must be a good balance between information and usability, which means that the data should be bring to the user in the more easy to handle manner. This part explains the data path from the dwelling to the final user, from smart meter to Internet browser.

Data harvesting and storage

In France, the smart meter deployment is not completed yet; for the purpose of the Grid-Teams project we enjoy the help of the smart meter made by Wit, a French SME, targeted for industrial activity. This meter is able to measure, collect, store and send data for a huge list of commodity and time slice. On our experiment three commodities were monitored, [Table 1](#), and took as input for both the thermal model and the final display.

Commodity	Unit	Monitor with	Send every...
Power	W	Amper clips after main electrical meter	time a trigger of 50 W is activated
Energy	Wh	Amper clips after main electrical meter	hour during the day two hours at night
Temperature	C°	Thermometer	hour time a trigger of 2° is activated

[Table 1 - Commodities monitored in the Grid-Teams project](#)

Three kinds of data sharing information on the three fields characterized earlier see infra p.2. Power and Energy spend were needed to level and understand the electricity consumption but also to assess user equipment rate and to profile usages. In the mean time the inside Temperature was useful to compute the stress on heating devices; to well understand this fight for heating we also collect external temperature to have an amount of degree to beat.

Once collected at the box level, data were sent via the general packet radio service (Gprs) protocol to the Wit datacenter, then forward to GridPocket Datacenter where data were pre-processed for the display on Web Interface. The architecture, [Table 2](#), built on open source technologies helps the data consolidation and display.

Architecture layer	Technology
OS	Ubuntu
SGBDR	Postgresql 8.4.8
Application Server	NodeJs
Web Server	Nginx

[Table 2 - Web Display architecture](#)

Web Interface vs. In-home display

In the Grid-Teams project we choose the Web Application display instead of an In-home one because of the lighter development, the cheaper cost and the agility of the process. That means in a large-scale deployment to deal with the Web Access. By agility and large scale of features, we mean examples shown in the next paragraph.

Features

The design process involved final users in a co-conception process, to ease the service's acceptability by all users. There is two ways of displaying data in Grid-Teams, on one hand a simply informational way and on the other hand an augmented way, to nudge the energy efficiency. The second one involves some analyses and engines, when the challenges of the first stay in the best way to display the chart and plot to be understandable¹.

¹ Finding the good shapes and design for plot and graph are not as easy at it seems, these challenges need ergonomics and designer skills. Within this project, with a lack of support in this fields we exchange directly with the users.

Energy data

The way people consume energy could be display through different displays, from a gauge at a specific moment, Figure 3, to a time series with the choice of commodity to display, Figure 5, Figure 4.

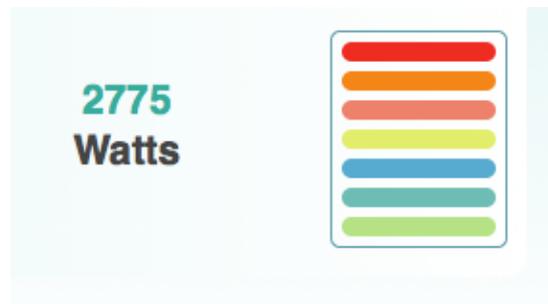


Figure 3 - Wattmeter

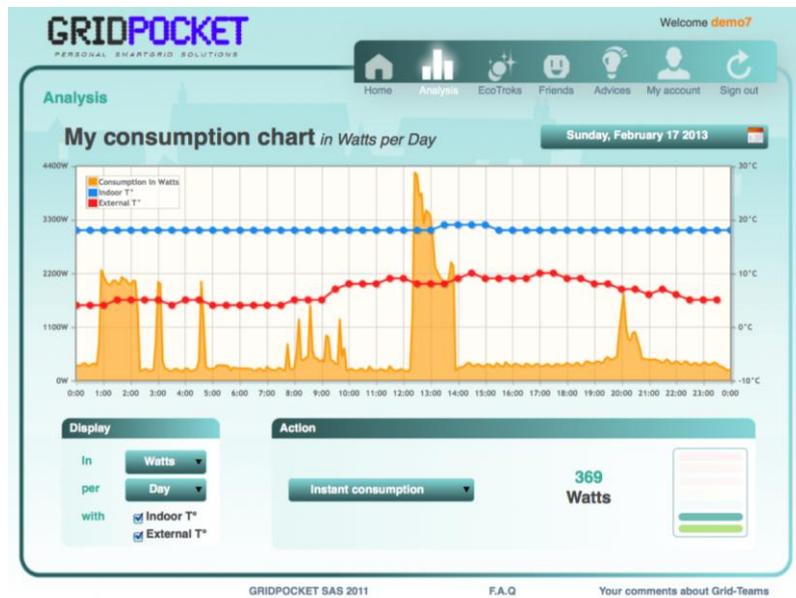


Figure 4 - Load Curve for user Demo 7 the 17th feb.



Figure 5 - Energy by hours within a day

Without help these information were already useful, but in some aspects quite difficult to handle and were not that easy to start switching for an energy efficient behavior. Other tools were offered to help the action to start.

Currency data

Speaking in technical terms, like the energy data above, can be sometimes hard to understand, so we decide to translate energy consumption to money.



Figure 6 - From energy to money

Scale and loyalty program

An important thing to do to motivate the participant and to keep him in the dynamic of the project is to show them bounds. The fact to show that you have to stay away from your upper bound and that you have a lower bound that is reachable is crucial. These bounds have been converted into currencies but are calculated with the thermal building knowledge, the appliances and behavior of the concerned candidate. Figure 7 show what the candidate can see on his interface.



Figure 7 - Energy Scale

Showing bounds permit to assess the efforts that have been made, but for energy savings, due to relative low gains that can produce a real effort, a supplementary action has been integrate to the project. It is the reward mechanism that we have called EcoTroks TM. This reward is calculated regarding the level of effort that can be shown on the previous figure. If the candidate has reduced its consumption during the previous week, it earns some EcoTroks. The calculus of the level of EcoTroks earned by the candidates regarding their specific case is not explained in the present paper. With their EcoTroks, the families can choose rewards on a dedicated WebSite. When it is validated, they can go to the town hall of the city of Cannes to take them. It is the city of Cannes that has provided the rewards for the project. The figure below represents the screen shot of the EcoTroks Shop.



Figure 8 - The program's shop

Experimentation and results

Enrolment of the candidates

The project consist in an experiment conducted on a reduce sample to validate the methodology describe in the previous section. The first step was to proceed to the selection of a representative panel of family that corresponds to the different constraints we have decided previously. To be able to manage such experimentation we decide to choose specific housings principally renters with electrical heaters. We also decide to have various types of families (singles, families with children ...).

The selection process was a project's milestone; the enrolment goes through a public advertisement and with the help of a city database of green association². The sociologists have provided some questionnaires to manage the final choice for the experimentation. A panel of 30 families has been chosen at the beginning of the study and at the end of the project, 20 families have conducted the complete experiment. Some of them have given up because of a lack of time or because they have changed their housing. Several causes have been identified but the majority hasn't given up due to their lack of interest in the project.

Smart metering

For each family a smart meter design, built by WIT was installed. This smart meter was programmed to send to the data center of the project every change in the power level as it exceeds 50 watts (See previous part above). The project will assess the capacities of the use of such devices in helping distribution grid operator (DGO) to have a better understanding of final user's behavior. In our experiment, this metering and the frequency of data transmission have a key role in the analysis we can produce and for the representation we want to show to the final user.

Sociological questionnaire survey

For each family that has been enrolled in the experiment, a Sociologist has met the family and several individual and group meetings have been made to explain the purpose of the project and to assess the characteristics of the candidates in term of their level in the energy management feeling at the beginning of the project. Each interview of the candidate has been recorded (audio and video) with the authorization of the participant and the interviews have been transcribed and analyzed. The procedure of explanation in several stages is very important in the acceptance process of the project. This kind of information is essential to be able to establish the progress of the candidates during the project and their ability to continue in the same way.

Results

From a one year experiment a lot of feedbacks were significant for all the partners from the smart grid deployment point of view, technical issues, marketing tools to be improve, thermal model

One of the main results is the involvement within the loyalty program; orders were sent during all the program time.

From energy efficiency perspectives the results need to be improved and tested in a larger scale, but first analyze brings a reduction close to 10 % from an assumed consumption as usual. The loyalty program EcoTroks played a significant role in this dynamics. The two figures below, show two different situation, Figure 9 shows an user earning and spending EcoTroks (TK) in the Grid-Teams shop, we can see a consumption stick to the target while an other user, who didn't care about the loyalty program, who was more erratic (and sometimes even more efficient) and finally less efficient in average.

² UN's Action 21 for the twenty-first century was implemented by french government in an "Agenda 21" plan where cities and local government were able to labelise associations and other green actions groups.

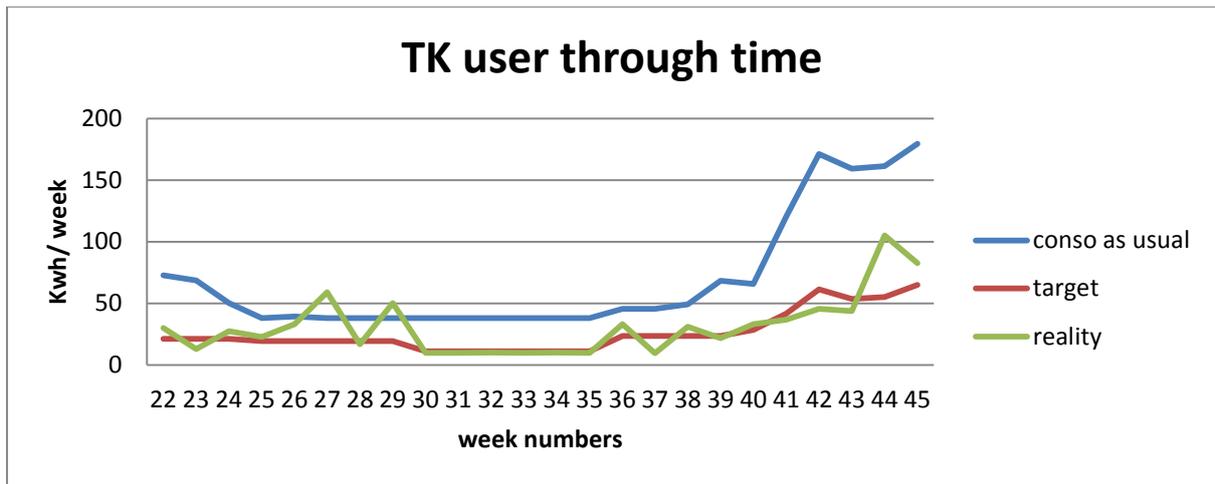


Figure 9 - User with TK gain, with a real consumption close to the targeted one

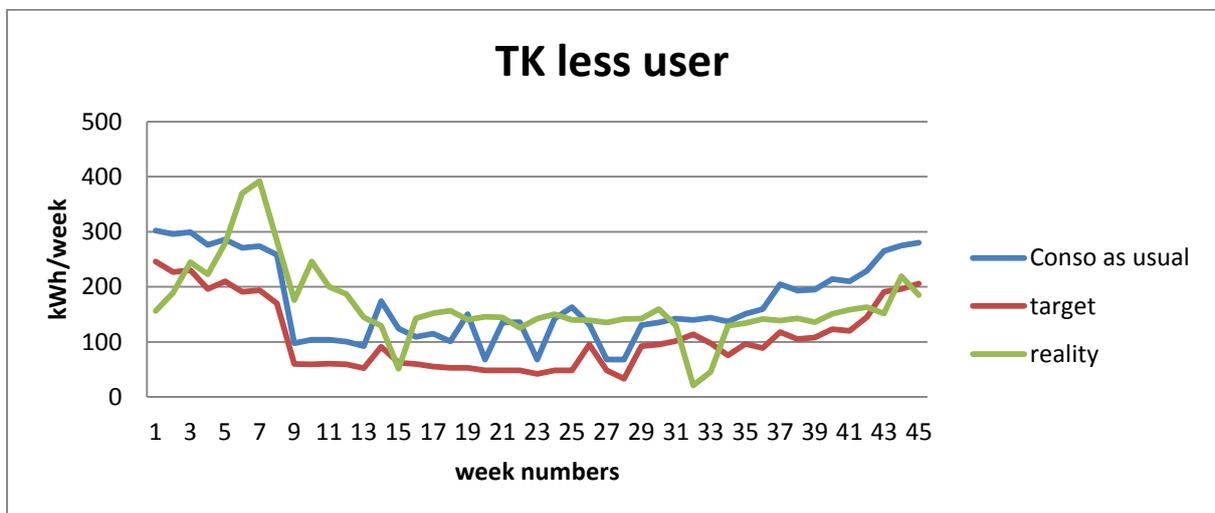


Figure 10 - User without TK, no clear path followed

Conclusion

The Grid-Teams project was an opportunity to test the potential of a smart meter for residential users in a way of energy reduction. The project shows that with a fine data collection, a fine analysis with a sociologist team, families can be involved in an energy management process. The methodology shows that we need some preliminary questionnaires (for the building part and for the inhabitant part) and a quick sample for the electricity consumption to be pertinent in our assessment of the family behavior. The results for the families are really encouraging. They validate the concept of the kind of information we have to provide to the families by our web interface to make them involved in a way of a sustainable reduction of their use of energy.

This is a first step towards robust tools that could be deployed at a large scale as soon as the smart meters will be available. A following project is forecast in this way to test the part that we couldn't test during this project. It is the social implication of the family regarding other similar families. A specific web interface was studied to imply a group of families and to put some competitions between candidates through the social networks to encourage them to reinforce their effort with the comparison they would make between each other.

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