The diffusion of smart meters in France

A discussion of the empirical evidence and the implications for smart cities

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Received 13 April 2015
Revised 1 June 2015
Accepted 3 June 2015

Abstract

Purpose – The purpose of this paper is to study business models (BMs) for smart meters (SMs) and discuss related issues in the French institutional context. Because SM introduce deregulation on both the demand and supply sides, the authors argue that they represent an opportunity to "unlock" the system by enabling feedback to consumers. The authors discuss the empirical findings from the TICELEC (*Technologies de l'Information pour une Consommation Electrique* – Information Technology for Sustainable Electricity Consumption Behaviors) project which is an experimental initiative to measure potential energy savings through the implementation of SM, and to test behavioral change.
Design/methodology/approach – The empirical data are from the TICELEC project and refer to a municipality in southern France. The project was designed to show the qualitative changes deriving from a new technology, and the quantitative changes in the form of real reductions in residential electricity consumption in the short and medium terms. The authors discuss these changes and their potential replication, and examine the nature of the feedback provided to users and the implications for SM BMs for France and for smart cities more generally.
Findings – The authors suggest that the opportunities provided by SM have to be compared with other kinds of intervention such as self-monitoring procedures. The results show that any intervention is important for moderating the sole impact of SM. The findings on the importance of changes to "energy habits" relate mainly to "curtailment" and "low efficiency" behaviors, which represent less costly changes. The lessons learned for BM developments linked to SM include incentive systems, smart tariffs, and technologies to increase potential behavior changes and energy savings in this field.
Research limitations/implications – The authors' analysis of the content of behavioral change shows that curtailment behavior and low-efficiency behavior remain dominant when SMs are implemented. Promoting high-efficiency behaviors is always difficult for reasons of cost. Thus, SM should be combined with other measures such as incentives systems, e.g. "smart tariffication," and new services to increase their impact.
Practical implications – A proper combination of smart tariffs and SMs to reduce peaks in demand would appear to be critical to boost SM development. It will also be important to integrate SMs with smart grids to improve energy efficiency and exploit renewables and energy storage in electricity networks.
Social implications – SMs are important but any interventions that motivate households to change their energy habits also help in the French context. SMs enable households to try to reduce their energy consumption but they are not the solution.
Originality/value – There are no detailed results published for France. Utilities such as Electricite Reseau Distribution France, have introduced R&D programs oriented to the deployment of SM which have been tested since 2009 (e.g. see the local LINKY meter projects in Lyon and Touraine). The empirical data are from the TICELEC project and refer to a municipality in southern France. The project was designed to show the qualitative changes deriving from a new technology, and the quantitative changes in the form of real reductions in residential electricity consumption in the short and medium terms. The authors discuss these changes and their potential replication, and examine the nature of the feedback provided to users and the implications for SM BMs for France and for smart cities more generally.

Keywords Feedback, Consumer behaviour, Habits, Business models, Residential consumption
Paper type Case study

Journal of Strategy and Management
Vol. 8 No. 3, 2015
pp. 231-244

1755-425X
DOI 10.1108/JSMA-04-2015-0034

1. Introduction

The European regulation concerning energy saving, notably Article 13 of the 2006 Energy Service Directive, has changed the rules of the games for utilities by introducing a link between metering systems and energy management, and encouraging implementation of individual meters to show real consumption combined with accurate billing (Darby, 2010). This policy has paved the way to a system of "learning by interacting" between utilities and households (Lundvall *et al.*, 2002), and the emergence of new business models (BMs) in energy fields. This goes beyond the diffusion of smart meters (SMs) in so-called smart cities, and allows households to save on energy and to reduce energy consumption. But do these new meters deliver what they promise: do they trigger real change in daily energy consumption? Recent studies show that feedback (Abrahamse *et al.*, 2007) and the deployment of intelligent networks (smart grids), SM, and intelligent electrical outlets such as smart plugs, may trigger change and boost energy reduction for households (Clastres, 2011).

Several recent studies show how households in various countries interact with diverse sources of feedback from smart energy monitors (Ayres *et al.*, 2009; Ek and Söderholm, 2010; Mizobuchi and Takeuchi, 2013; Sweeney *et al.*, 2013; Schleich *et al.*, 2013; Wall and Crosbie, 2009; Yu *et al.*, 2013). However, to our knowledge there are no detailed results published for France. Utilities such as *Electricite Reseau Distribution France*, have introduced R&D programs oriented to the deployment of SM which have been tested since 2009 (e.g. see the local LINKY meter projects in Lyon and Touraine) [1]. Although "learning by doing" and "learning by interacting" have been ongoing at the regional and local levels in France, the demand-side outcomes have been neither diffused nor published, and debate is open in this field[2].

Our empirical data are from the TICELEC project and refer to a municipality in southern France. The project was designed to show the qualitative changes deriving from a new technology, and the quantitative changes in the form of real reductions in residential electricity consumption in the short and medium terms. We discuss these changes and their potential replication, and examine the nature of the feedback provided to users and the implications for SM BMs for France and for smart cities more generally.

This paper is structured as follows. Section 2 defines the institutional context in order to obtain a better understanding of the existing players in France and the opportunities for the emergence of new BMs. Section 3 reviews the demand-side opportunities and the possibilities for behavioral changes. Section 4 summarizes the TICELEC experiment in France and the implementation of SM in southern France. Section 5 discusses the empirical findings and the energy reductions achieved for diverse groups of households. Section 6 concludes and discusses some implications related to SM BMs and potential replication of the experiment.

2. Prior BMs in the energy field: a long heritage from the national innovation system

The relation between electricity utilities and households in France is, as in many countries, a social construct inherited from the past – especially the decades following the end of Second World War when several critical investments were undertaken and technological options exploited, including General de Gaulle's choice to invest in nuclear plants (Cowan, 1990; Teravainen *et al.*, 2011). These decisions have shaped the socio-material conditions and relations between utilities and households (Chick, 2002; Marty, 2007). These technological priorities were driven by a willingness to provide cheap and abundant electricity to French households. Accordingly, in France (and also in the USA) the design of prices and tariffs did not include feedbacks to consumers (Yakubovich *et al.*, 2005). Particular investments and types of public infrastructures have created a specific link to consumers which explains current energy habits and practices, generating a kind of path dependency that precludes behavioral changes (see Maréchal and Lazaric, 2009). As a result, in France, the electricity utilities and the main provider, *Electricité de France*, have been delivering electricity at lower prices per Kwh compared to other European countries (Eurostat, 2013), resulting in the expectation of low prices and lack of awareness among consumers about their daily consumption (Keppler and Cometto, 2013).

The deployment of smart grids, and the requirement imposed by European legislation are raising questions about energy security and climate changes objectives (Clastres, 2011). The price of electricity per Kwh is being debated, and opportunities for increasing tariffs to take account of the full cost of maintenance of nuclear plants are becoming serious issues for households in France (Finon and Glachant, 2008; Salies, 2010). In this context of change in the energy sector, deployment of smart grids and SM is introducing new opportunities in the electricity value chain, improvements to the overall management of electrical systems, and potential gains for consumers. Reducing the asymmetry between demand and supply is a critical component of this transformation for learning about demand-side determinants and for discovering future strategic investments in this field (Manral, 2010, 2011; Pehrsson, 2011). SM can be employed to monitor and allow more control of daily energy consumption and increase economic and ecological awareness among French households. Energy has always been perceived by households as an invisible commodity (Thaler and Sunstein, 2009, p. 206; Hargreaves *et al.*, 2010; Maréchal, 2010), and its invisibility has been accentuated by local and historical conditions, which has provided opportunities for introducing changes and testing new BM for the renewal of the energy sector in France.

3. Energy-inefficient habits and the opportunities provided by SMs

It is acknowledged that better control over energy consumption, particularly electricity, requires both technological innovation and profound behavioral change to encourage sustainable habits (Geller, 2007). As early as 1899, Veblen pointed out that consumers are not always aware of their daily consumption practices.

The literature in this area shows that generally, consumer behavior is based on habit and repetition, extending even to the cognitive acts of individuals. This behavior could be harnessed to encourage energy saving habits at the national level. We need to understand what has been described as the "paradox of efficiency in energy consumption" (DeCanio, 1998; Maréchal, 2009). Maréchal and Lazaric (2010, pp. 14-15) suggest that the existence of energy-inefficient habits of life may provide one explanatory factor of this paradoxas:

> […] a lot of everyday energy consumption corresponds to this unconscious forms of built-in consumption practices […]. Indeed, the decisions taken in everyday energy consumption are likely to be considered as having less than significant consequences – other decisions.

In France and in Europe generally, households are poorly informed about their electricity usage practices, and have no control over prices. Several studies show that the information provided on electricity bills does not allow consumers to identify changes that could be introduced to their behavior, or to link a reduction in consumption to their equipment or habits (Wall and Crosbie, 2009). Welsch and Kühling (2009, p. 168) note that economizing on cognitive effort in the choice process can be achieved by using a behavioral benchmark based on past behavior and the behavior of referents: "The importance for consumer choice of the behavior of reference persons derives not only from considerations of cognitive effort but, in addition, from consumption's role as a means of achieving social compatibility and expressing social identity" (Welsch and Kühling, 2009, p. 168). These limitations can affect decisions about consumption practices and environmental considerations (Bartiaux, 2006; Halkier, 2001). Mental compartmentalization allows some consumers to keep "green reflections out of certain practices" (Halkier, 2001, p. 39) and to exhibit a kind of self-defense against daily practices and decisions that contradict the norms of comfort and convenience in everyday life (Shove, 2003; Lynas, 2007). By employing "mental zapping," the attention of households can be diverted from acknowledging the necessity to reduce energy consumption by making significant changes to daily life (Sweeney *et al.*, 2013). For example, saving energy through "efficiency behavior" in the form of buying more efficient appliances or investing in structural changes to the home may be postponed, while "curtailment behaviors" to save energy through reduced use may be more acceptable because they require lower costs and minimal changes to habitual actions (Karlin *et al.*, 2014). Indeed the invisibility of energy consumption (Maréchal, 2010) combined with in the absence of feedback to consumers (Sweeney *et al.*, 2013) may reinforce the tendency of individuals to procrastinate over required changes and to maintain the status quo (Samuelson and Zeckhauser, 1988)[3].

In this context, feedback can promote changes to behaviors and energy practices in certain contexts (Darby, 2010). The feedback provided must be understandable, and clearly related to the technology. Results for the USA show average savings ranging from 0 to 7 percent (Allen and Janda, 2006; Parker *et al.*, 2006) to 0-18 percent (MacLellan, 2008; Mountain, 2008; Scott 2008). Abrahamse *et al.* (2007) examined the effect of a feedback tool available on the internet which has helped European households to generate average savings of 5.1 percent. For the Netherlands, Benders *et al.* (2006) found an average reduction of 8.5 percent, while empirical findings for Japan indicate reductions of up to 18 percent in power consumption (Ueno *et al.*, 2005; Ueno and Nakano, 2006). These results depend on the nature of the feedback received. Some empirical findings are based on self-monitoring procedures (with improved billing, or weekly billing), while other studies explore the effect of direct feedback (real-time information on energy consumption, or detailed information at the appliance or "real-time plus" level).

4. The TICELEC project and SM implementation

In the context of these triggers and incentives in the French household energy sector, we conducted an experiment called TICELEC to introduce SM in Alpes Maritimes in Southern France, in a region where policy makers scrutinize energy consumption and supply in order to calculate future consumption at the local level (IAE, 2012). The experiment was implemented in Biot, a municipality close to Sophia Antipolis, well known for its introduction of information and communication technology (ICT) solutions. Biot has launched several projects related to sustaining ecological awareness among households and encouraging sustainable consumption, good waste practices, and consumption of locally produced food.

The project was overseen by academics from the University of Nice Sophia Antipolis and involved three main actors: a startup called Ubinode, the Biot municipality, and OFCE (The French Economic Observatory). The roles of these actors were well defined. The experiment was designed by the university actors and OFCE, and the messages sent to households about potential energy consumption savings were carefully composed.

The municipality, guided by the university actors, was responsible for communicating with households and recruiting participants. Ubinode, the startup, provided ICT devices to monitor electricity consumption (SMs with ergonomic interfaces with home computers, called the "Home Energy Pack"). The Home Energy Pack facilitated direct feedback to households to enable a better understanding of the structure of their consumption. The package consisted of a web application and sensors which could be installed in various locations in the home and provide feedback representing near "real-time information" on general consumption and detailed information or "real-time plus" feedback related to individual appliances.

5. The story of the project and data collection

The project was officially launched on April 1, 2011 and terminated officially on May 24, 2013. It involved the following five phases:

(1) recruitment of households, meeting with households, and assignment to different feedback groups;

(2) installation of the SM;

(3) collection of consumption data; and

(4) testing and treatment of results.

The timeline is summarized in Figure 1.

The recruitment phase involved recruiting volunteers and ran from April 2 to September 30, 2011. The resources in the form of communication tools provided by the Municipality of Biot (display, web site, magazine, social networks, and educational leaflets) were put in place, and information disseminated by press releases and flyers delivered to households showing the involvement of the municipality in the project: 172 volunteer households were enrolled in the experiment.

After being recruited to the project, the household head received a seven question survey designed to identify the type of electricity meter in the accommodation, and check the presence of an internet connection and the distance between the internet connection and the meter. The responses from the survey allowed identification of those households where some adjustments were needed. Collection of the questionnaires was completed by October 1, 2011 and resulted in a sample of 141 respondents. The participating households were allocated to three groups: self-monitoring (group 1), real-time feedback (group 2), and real-time plus feedback (group 3). A meeting was held to explain the project and its different phases. Meetings were held with each group separately on October 18, 19 , and 20, 2011. The smart equipment was provided to groups 2 and 3 on October 19 and 20.

The next phase was installation and connection, which continued to December 31, 2011. In this period only 124 households were following the experiment; some prior intentions to join the project were not followed by concrete acts and in some cases personal situations or external contingencies such as house moves had intervened. On January 1, 2012, a second questionnaire was administered. This included more specific questions on type of housing, consumption habits, household composition, and opinions on environmental issues and sustainable development. This data collection phase lasted eight months until August 31, 2012. During this phase, some households left the project for family reasons (moving, divorce, other), technical reasons (sensors that did not transmit the information due to the thickness of the concrete walls despite compliance with the recommended maximum distance of 20 meters between the

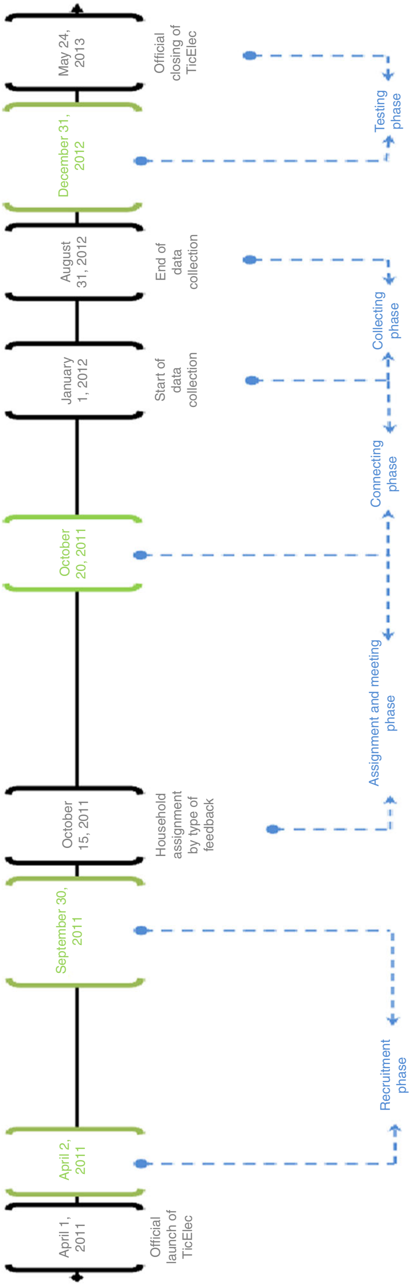


Figure 1.
Timelag of TICELEC project

broadband router and the meter), or lack of motivation. This reduced the number of households to 80. During this stage, households were invited to attend a meeting held on June 26, 2012. Most of the participants were from group 1. The questions posed and interventions made during this meeting reflected some frustration over the lack of information on consumption despite twice-monthly submission of meter readings.

By the end of this stage, 80 households had received the end-of-study questionnaire which asked about their use of equipment, all the changes that had been made to their homes or the composition of their household, their level of satisfaction with the feedback received, and changes to habits. The responses received represented a complete collection of data before and after the experiment, from 65 households distributed as follows: 35 with a simple self-monitoring meter reading and no SM, 14 with direct feedback type "real-time," and 16 households with direct feedback type "real-time plus."

To summarize, our final and (retained) sample is 65 households split into three sub-samples. Subsample 1 is the control group with self-monitoring, consisting of a set of participating households which were not given real-time feedback but were asked to read their meters twice a month. Subsample 2 includes households where the Home Energy Pack was incorporated into the general meter allowing direct "real-time" feedback. Subsample 3 had two sensors installed in the house, and the energy pack installed on the main meter; this group received the most detailed information on their energy use via direct feedback type "real-time plus."

The project was officially closed on May 24, 2013 with a meeting between the participating households and the project funders, where the results of the test phase from January 1, 2013 to May 24, 2013 were presented.

6. Results and analysis

Among diverse initiatives making energy resources visible to residential consumers, Ehrhardt-Martinez *et al.* (2010) indicate in the USA a comparison of feedback results showing that the "real-time plus" is best for reducing energy consumption (about 14 percent), followed by feedback in "real-time" (about 9 percent). On average, direct feedback compared to indirect feedback resulted in a reduction in consumption of 11 percent compared to 8 percent. The results are presented in Table I.

The results of studies on feedback vary depending on the sample size, duration of study, and the regional context. The average sample size is 60-600 participants. The number of participants has important implications for energy savings related to feedback. Most previous studies lasted between two and 12 months (average five months). By examining the relationship between the duration of the energy savings related to feedback, and the type of feedback received, we see that energy savings are significant for shorter observation times (Lehman and Geller, 2005) (Table II).

Type of feedback	Energy saved (average) (%)
Enhanced billing	5.2
Estimated feedback	6.8
Daily/weekly feedback	11.0
Real-time feedback	8.6
Real-time plus	13.7

Source: Ehrhardt-Martinez *et al.* (2010)

Table I. Energy savings from different kinds of feedback

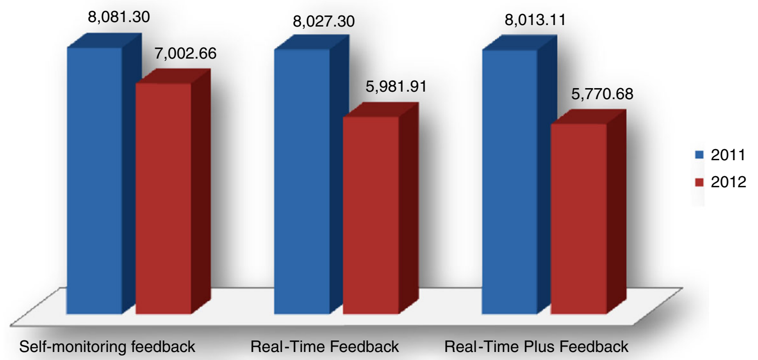
In TICELEC project, comparison of average annual consumption in our sample among groups with direct feedback (groups 2 and 3) and self-monitoring feedback (group 1) before the project (in 2011) and during the project (2012), shows that the highest reductions were obtained by the groups with direct feedback (−22.4 percent in Kwh) compared to the group that was self-monitoring (−13.3 percent in Kwh). As expected, our empirical findings confirm the gap between the self-monitoring group and groups 2 and 3 related to achieving energy reductions, and that the difference between the real-time feedback and real-time plus feedback groups is small at around 1 percent (see Figure 2).

To test for behavioral change and the content of this adjustment, it is useful to apply the notions of "curtailment" and "efficiency" behaviors. According Gardner and Stern (1996), "curtailment behaviors," to be effective, involve reducing consumption, and repeating actions, while "efficiency behaviors" are one-time behaviors involving the adoption of efficient technologies whose use provides continuous benefits. Nair *et al.* (2010, p. 2956) distinguish these as non-investment efforts based on "existing or altered habits," and measures that are infrequent and require a one-time investment which may be costly for the household. They distinguish also between "low investments" such as buying eco efficiency appliances, and "high investments" such as building repairs, and/or installing insulation and new heating systems (Nair *et al.*, 2010; Sweeney *et al.*, 2013).

Table II.
Savings by feedbacks, according the sample, the size, and length of the experiment

Type of intervention		Similar experiment Less than 100 households (%)	(Length: more than 6 months) (%)	TICELEC 65 households 12 months (%)
Self-monitoring and indirect feedback	Self-monitoring feedback	–	–	13.3
	Enhanced billing	–	5.1	–
	Estimated feedback	–	–	–
	Daily/weekly feedback	12.4	16.5	–
Direct feedback	Real-time feedback	10.7	7.3	22.2
	Real-time plus	12.2	–	23.3

Source: Authors' research



Source: Authors' research

Figure 2.
The average electricity consumption between 2011 and 2012 according groups (Kwh)

In relation to curtailment behavior, we selected the variables "lights off in unoccupied rooms" and "setting the device to sleep mode after use" (see Table III). In relation to the first variable, 90 percent of households with direct feedback extinguished lights in unoccupied rooms resulting in an average saving of nearly 3,000 Kwh/year. Thus, the behaviors of groups 2 and 3 are almost identical.

The practice of setting devices to standby mode after use was similar among the groups. More than 60 percent of the sample that received direct feedback adopted standby mode after use resulting in a saving of 700 Kwh/year. Again the behaviors of groups 2 and 3 exhibit similar practices, and we cannot conclude that the nature of the direct feedback is significant here.

In relation to efficiency behavior, we selected the variable "number of low energy light bulbs" (see Table IV). Similar to our findings for lights in empty rooms, we observed that 90 percent of households with direct feedback used low-consumption lamps or opted for the latest eco-efficient lamp during the experiment. The proportions

	Feedback		
	Real time	Real-time plus	Total
Extinguishing lights in empty rooms between 2011 and 2012	1	2	3
(–) and (– –)	33.3%	66.7%	100.0%
Extinguishing lights in empty rooms between 2011 and 2012	13	14	27
(+) and (++)	48.1%	51.9%	100.0%
Standby mode after use	5	7	12
(–) and (– –)	41.7%	58.3%	100.0%
Standby mode after use	9	9	18
(+) and (++)	50.0%	50.0%	100.0%

Notes: (– –), Deterioration and non-efficient change of habits: households had sustainable habits in 2011, but they were discontinued in 2012; (–), no change habits (habits inefficiencies): households never had sustainable habits, in either 2011 or 2012; (+), no change habits (habits efficient): households practiced sustainable habits in either 2011 or 2012 and these did not change; (++), improvement of habits: households had no sustainable habits in 2011 but adopted them in 2012
Source: Authors' research

Table III. Restriction behaviors responding to direct feedback

	Feedback		
	Real time	Real time plus	Total
Difference in the number eco-efficient lights bulbs installed between 2011 and 2012	1	2	3
(–) and (– –)	33.3%	66.7%	100.0%
Difference in the number eco-efficient lights bulbs installed between 2011 and 2012	13	14	27
(+) and (++)	48.1%	51.9%	100.0%

Notes: (– –), Deteriorating habits: households that owned or applied in 2011 but ceased to possess or apply in 2012; (–), negative stagnant habits: households that did not own or apply in 2011 and continued this way in 2012; (+), positive stagnant habits: households that owned or applied in 2011 and continued to possess or apply in 2012; (++), improved habits: households that did not own or apply in 2011 but did own or apply in 2012
Source: Authors' research

Table IV. Low-efficiency behaviors responding to direct feedbacks were similar (i.e. 90 percent of households) in groups 2 and 3 achieved average annual savings of nearly 70 Kwh . Added to the average annual saving of 3,000 Kwh based on extinguishing lights in unoccupied rooms, we can say that the source of this efficiency behavior is driven mainly by good control over demand for electricity.

Finally, we are interested in types of high-efficiency behaviors and their potential for change during the experiment. We chose the variables "energy investment" and "investment in insulation" (see Table V).

Only three households made energy investments and one household in 30 had installed insulation in their homes. This reveals that high-efficiency investments have a low impact on both groups 2 and 3. This result is mainly due to cost, which is a problem for households for which SM are not the solution.

We can conclude that the direct feedback provided to households has a positive effect mainly on curtailment behaviors. The cost of restriction behaviors and non-investment measures is relatively small, and is flexible, allowing for rapid implementation for households interested in changing their behaviors. Efficiency behaviors are more difficult to implement because they require some level of investment by the household. The results of these changes are not always observable in the short term which can result in households procrastinating over large, long-term investments.

7. Conclusion

SMs are in their infancy in France, and their BM is difficult to predict at this stage. However, new regulation is providing opportunities to adjust the electricity value chain in upstream (generator) and downstream markets. SM are only one component in smart grid developments, and involve new market players and effective deregulation of the electricity and gas industries. In this context, experience from SM diffusion is relevant for new BMs and smart buildings.

Our empirical findings from implementation of the TICELEC project in France shows how much households may change their habits and increase their behavior change. The achievement of important savings on electricity consumption by the groups with direct feedback (groups 2 and 3) as well as the self-monitoring group is a significant finding. It shows that SMs are important but also that any interventions that motivate households to change their energy habits also help. SMs enable households to try to reduce their energy consumption but they are not the solution. Our analysis of the content of behavioral change shows that curtailment behavior and low-efficiency behavior remain dominant when SMs are implemented. Promoting high-efficiency

		Feedback		
		Real time	Real-time plus	Total
Insulation measure	No	12	15	27
		44.4%	55.6%	100.0%
	Yes	2	1	3
		66.7%	33.3%	100.0%
Insulation investment	No	14	15	29
		48.3%	51.7%	100.0%
	Yes	0	1	1
		0%	100.0%	100.0%

Source: Authors' research

Table V. High-efficiency behaviors responding to direct feedback behaviors is always difficult for reasons of cost. Thus, SM should be combined with other measures such as incentives systems, e.g. "smart tariffication," and new services to increase their impact. A proper combination of smart tariffs and SMs to reduce peaks in demand would appear to be critical to boost SM development. It will also be important to integrate SMs with smart grids to improve energy efficiency and exploit renewables and energy storage in electricity networks. These efforts would pave the way to the establishment of smart cities. Given the institutional context in France, there is much that could be done to include consumers and citizens in the development of new products and services, and transform current industry BMs. Deregulation should be considered an opportunity to push these transformation at the levels of both demand and supply, in particular because cognitive "lock in" and technological lock will continue to dominate this field.

Acknowledgments

The research for this paper was financially supported by the REGION PACA programme *Agir ensemble pour l'énergie* – Grant No. 1140C0397 – , the *Conseil Général des Alpes* Maritimes (CG 06), and the ADEME Marseille – Grant No. 19364-22937. The authors would like to thank the colleagues and collaborators of the TICELEC project who provided insights and expertise, notably Sébastien Alegret, Martine Aufeuvre, Amélie Bourgeois, Olivier Brie, Mathieu Pinson, and Evens Salies. As usually said, the views of this paper are solely the responsibility of the authors and potential errors remain their own.

Notes

1. According to French utilities, ERDF has been testing its Linky meter in a roll out of 300,000 meters in Touraine and Lyon since 2009. In addition, more than 25,000 LINKY meters have been deployed in the approximately dozen other smart grid pilots that ERDF currently has underway across France (Smart meter.com July 13, 2013).
2. See especially criticisms of the management of these new services, and the hidden costs borne by consumers detailed in a consumer review (Survey published by Que choisir, September 24, 2013).
3. "Most real decisions, unlike those of economics texts, have a status quo alternative-that is, doing nothing or maintaining one's current or previous decision" (Samuelson and Zeckhauser, 1988, p. 7).

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