Smart gas meters: assessment of customer response to improved information about their energy consumption

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Abstract

By paving the way for a massive roll-out of smart metering systems, the European Commission raises the question of their impact on household energy consumption. Could smart meters play a significant role in improving customers' understanding of their energy use and thus promote action to reduce energy consumption? Studies have mainly focused on electricity consumption and the impact of real-time feedback, which are in some cases linked to demand-response programs. Few have been addressing the impact on gas consumption.

In order to build a step-by-step understanding of customer response to improved information about their energy consumption through the use of smart gas meters, we develop a methodology taking into consideration [1] improved information available to the customers at no additional cost [2] new services enabled through the use of gas smart meters [3] improved information to be provided to third parties such as local authorities or social landlords.

In the France case study, we base ourselves both on field tests carried out by GrDF, focusing on 18,500 smart meters and a comprehensive survey conducted among 400 households, and statistics provided by the French Environment and Energy Agency (ADEME). Even with a conservative approach, this assessment points to increased impact on gas savings of the deployment of gas smart meters compared to the French Energy Regulator (CRE)'s first theory-based assessment. Thus, energy conservation is becoming the main rationale to justify an overall roll-out of gas smart meters to every consumer in France.

Introduction

Many countries made energy efficiency one of their priorities in response to the first oil crisis. France has achieved significant results thanks to improved insulation, resulting from proactive regulations on new buildings and incentives on renovation. Since 1973, despite the fact that the French residential sector has doubled in size, it has achieved savings of -50 % in the average consumption of domestic heating per unit of surface area and -30 % in CO_2 emissions. Nevertheless, as demonstrated by Schipper, L. et al., variations in energy use are influenced by many factors besides the characteristics of a heating system's efficiency or the thermal integrity of a building, which only account for 50 %. Finding levers for energy savings based on behavioural changes appear to be needed in order to meet *Facteur 4* requirements, which aim at a fourfold reduction in French greenhouse gas emissions by 2050.

Today, there is a discrepancy between [1] opinions of individuals, which reveal a growing ecological awareness and a willingness to reduce energy expenses and [2] actual practices, which tend to increase household energy consumption. A British study conducted on consumers from 10 European countries showed that 80 % felt concerned about global warming, but 45 % did not know how much energy they used. In a 2008 survey, two in three French people stated that they wanted to reduce their consumption by cutting down on heating or air conditioning, but only half of them remembered doing so during the previous month. This gap is not a sign of irrationality, but shows the complexity of energy consumption dynamics. Dwelling and household equipment characteristics are related to observed evolutions in residential energy use as well: for instance, the widespread use of central heating during the 1970s in the United Kingdom led to an indoor temperature increase of 3 °C.

Another illustration of this complexity is the *rebound effect,* which is defined as the difference between the anticipated benefits of introducing energy-saving technical changes and the actual energy savings achieved. Energy-related research distinguishes between two kinds of rebounds: direct rebound refers to a more efficient, single item of equipment, which is used in a more intensive way; indirect rebound refers to savings that are transferred from one item of equipment to another. The drivers of this phenomenon are not only technical (the building's structure, the improved performance of equipment, etc.), but also sociological (energy use, changes in standards of comfort, etc.). For instance, a CREDOC study demonstrated that the temperature regarded as comfortable in the living room of a French household was strongly dependent on the date of the building's construction. The more recent the housing is, the more likely it is that the comfort temperature will be in excess of 20 °C. It highlights the link between technical performance and representations of comfort, which is a powerful engine for *rebound*. The drivers of this effect are difficult to identify because they vary from one household to another: so far, trials have not succeeded in accurately pinpointing the extent of the rebound effect. A British study in 2007 found that in the case of efficiency improvements in heating systems, approximately 30 % of the expected savings were absent (estimates were between 10 % and 50 %). The UFE also established this statistic.

These results, in addition to other consumer studies, demonstrate the need to keep users better informed about the impact of their energy practices. To achieve this, smart meters offer unprecedented possibilities for the understanding of consumer behaviours and, at the same time, will create new interfaces and tools to inform them efficiently about the best ways to reduce their consumption and decrease the impact on the environment.

Smart gas metering can impact the household's understanding of their energy use: actual gas consumption data is likely to change customers' perceptions of their energy consumption. Today, very few people tend to read their (gas and electricity) meters, which are often difficult to access. Customers' understanding of energy is currently based primarily on annual or monthly invoices including the cost of energy, which are not sufficient to make their actual consumption intelligible. Improved information could therefore help to develop an "energy reflexivity" which is the ability of individuals to assign a meaning to their practices and energy consumption choices. The English sociologist, Anthony Giddens, states that "the reflexivity of modern social life consists in the fact that social practices are constantly examined and reformed in the light of incoming information about those very practices, thus constitutively altering their character". This *discursive conscience* is not only a characteristic of modernity, but lies at the root of social change.

Smart gas metering can also impact a household's practices: focusing on gas consumption means focusing on thermal energy uses, which represent more than 80 % of domestic consumption. Above and beyond specific uses of electricity, they refer to fundamental human needs and involve a greater resistance to change. The associated energy uses (heating, washing, cooking) are conditioned by standards shaped by the course of history: the development of modern comfort in the living environment, central heating, and public policies. Furthermore, these gas uses require equipment over which consumers sometimes have little control. For instance, gas is predominant in buildings where industry professionals manage heating and domestic hot water systems.

For a public actor such as GrDF preparing to deploy 11 million gas smart meters in France, the aim is to understand the ability of the French smart meter known as *GAZPAR* to trigger energy efficiency improvement measures (EIM). To do so, armed with an international benchmark emerging from studies focusing on the impact of smart metering, the authors built an original and forward-looking approach in order to formulate a reasonable hypothesis concerning consumption savings made possible by behavioural changes. This method is based on the assumption that some consumers will decrease their gas consumption by implementing EIM as a result of information and services provided by the meters.

Demand response assessment methodology

In 2012, GrDF launched a task force together with the French Environment and Energy Agency (ADEME) aimed at assessing energy savings triggered by *GAZPAR,* the French smart gas meter. A European benchmark provided us with the chance to establish a preliminary assessment and the range of energy savings that would be enabled by gas smart meters, namely between 2.8 % (Gas Customer Behaviour Trial, Ireland) and 5.1 % (Kema, Netherlands). A major trail, involving 60,000 English households, concluded that smart gas meters allowed a 3.0 % energy use reduction (Energy Demand Response Program).

In order to carry out its own assessment through a bottom-up approach, the task force defined three patterns of demand response inspired by the energy behaviour typologies developed by W.F. Van Raaij. He described: [1] the purchasing behaviour: the purchase is influenced by the energy efficiency characteristics of the equipment., [2] the uses: daily use of household appliances and "small acts" to change it (frequency, duration, intensity of use..) and [3] the maintenance behaviours: the behaviours that effect the lifetime of the equipment, such as small repairs, upgrades, to maintain the equipment in good order to maintain good energy efficiency, such as defrosting the freezer, checking the heating system … In order to define the patterns and study their impact, the task force distinguished the three information vectors that lead to EIM and used input data that was available, sharable with our partners and using agreed-upon sources. The three patterns representing the pillars of our methodology are the following:

1. Demand response resulting from improved information about household gas consumption provided by suppliers or *distribution network operators* directly to the customers at no additional cost. *Input data: ADEME statistics, energy savings certificates, GrDF field tests, international benchmark.*
2. Demand response resulting from paid innovative services relying on meter data to which customers might subscribe: specific audit, alerts based on consumption levels, … *Input data: French Energy Service Companies (ESCOs) market research.*
3. Demand response resulting from improved information provided to third parties, such as local authorities or social landlords, who provide support to citizens and customers,

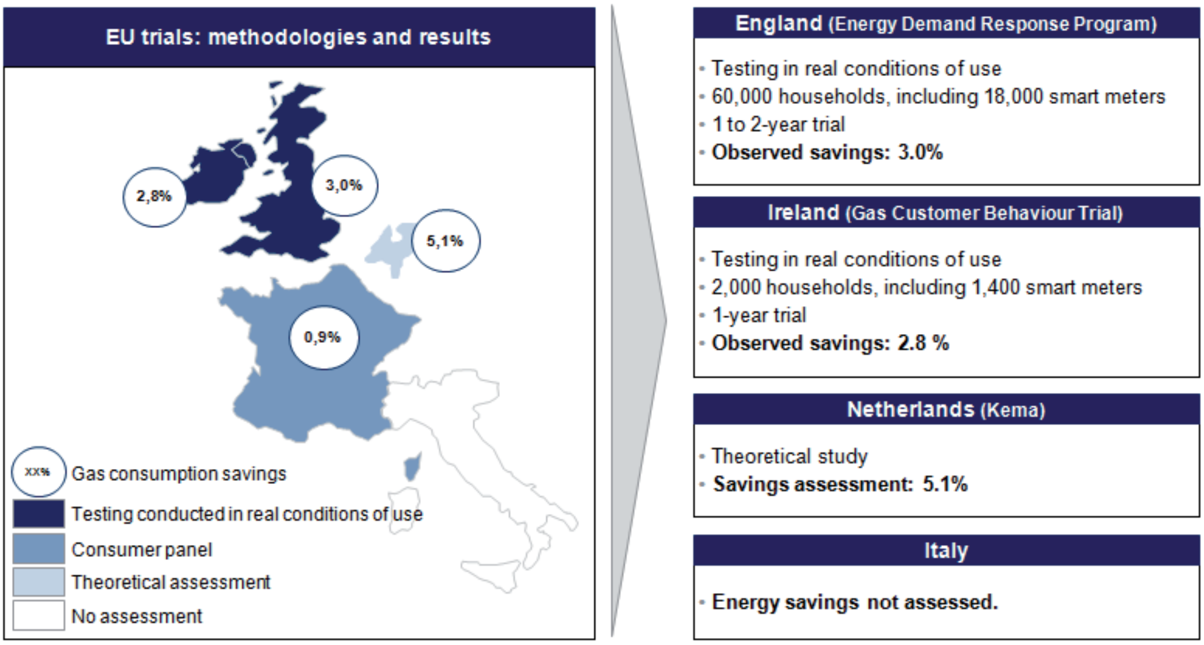

Figure 1. EU Trials: methodologies and results. Source: Pöyry, Sopra Consulting.

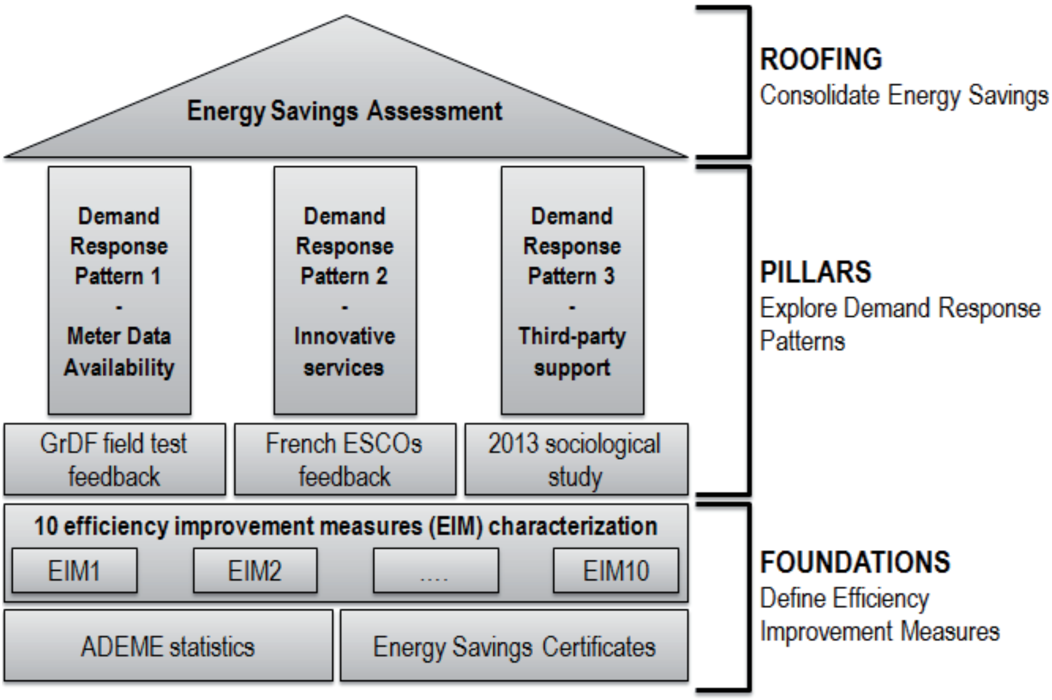

Figure 2. Methodology building blocks.

and implementation of behavioural policies and programs to promote energy savings. *Input data: dedicated sociological study to be carried out in early 2013.*

Given the information available and the level of certainty, we did not have enough data to document the third pillar and the decision has been taken to launch a study dedicated to smart metering benefits for third parties such as social landlords and local governments.

The bottom-up evaluation carried out starts with data concerning a single energy efficiency improvement measure, mechanism, program, or energy service (e.g. monitoring energy savings per participant and number of participants), and then aggregates results from all measures implemented to assess its total energy savings in a specific field. The major advantage of bottom-up evaluation methods (as compared to top-down methods, which make use of already existing and officially approved statistics) is the ability to monitor energy savings that are due to specific measures. This approach can thus achieve greater accuracy and offer additional advantages, as it enables the development of benchmarks and better program control.

Since energy efficiency improvement measures result from increased customer awareness of energy use, the energy savings assessment is based on [1] the number of households equipped with smart meters that will implement those measures and [2] the average impact of each measure. ADEME statistics, energy savings certificates (ESC), as well as findings from trials carried out by GrDF were used to build a common understanding and assessment of the impact of the gas smart meter.

Foundations: the foundations of the methodology are **ADEME statistics** and **Energy Savings Certificates (ECS)**, which enable us to characterize the impact of efficiency improvement measures on the average dwelling's gas consumption, using agreed-upon standards.

ADEME operates in various ways, mainly by providing the general public with specific information on existing technologies (white goods labelled "low consumption", energy-efficient boilers, individual solar-powered water heaters, heat pumps, insulation techniques, room thermostats and "green" tires and fuels) and energy-saving best practices. It has published a list of 100 eco-friendly actions recommended to customers, including an assessment of their impact on gas and electricity consumption. Eight of them concern energy efficiency improvement measures impacting gas consumption and have been taken as a reference.

In order to raise awareness among all sectors of civil society and encourage a sense of responsibility, French regulations have introduced a tool known as the 'energy saving certificate'. The principle behind this is that the government compels energy providers (electricity, gas, LPG, oil, for heating and cooling systems) to reduce energy consumption over a given period and to make energy savings via their customers. Providers are free to decide what type of action to implement in pursuit of this goal: informing customers on how they can reduce their energy consumption, running promotions in association with equipment retailers, etc. If the set targets are met in time, providers receive certificates as an attestation of the total savings achieved. Conversely, the treasury will fine providers if they fail to meet their targets. These certificates provide us with references concerning the energy impact of complementary actions that might not be listed by ADEME.

We use these validated data sets to build a summary overview of each efficiency improvement measure likely to be implemented: specific penetration rates, average impact on energy use (heating, domestic hot water or cooking) and duration limit distinguishing between residential and tertiary sector customers.

PILLARS: THE FIRST PILLAR FOCUSES ON METER DATA AVAILABILITY IMPACTS, WHICH ASSESSMENT IS BASED ON TRIALS CARRIED OUT BY GRDF

Between February 2010 and June 2011, GrDF, in collaboration with the regulator, meter manufacturers, local authorities and consumer associations, conducted 4 trials in 4 medium-sized cities, spread across the territory. In each of the cities, communicating gas meters have been installed. Aside from the technical challenge, the two aims of these field tests were as follows: [1] determining the services anticipated by all customers, as well as optional services, and [2] measuring the effects (feedback, satisfaction, impact on energy consumption) of the information provided by the meters on customer behaviors, by means of a qualitative survey conducted over 8 months.

Recruitment and description of panel

A 400-dwelling panel was built during a recruitment campaign in order to study household reactions to improved consumption information: smart gas meters were installed in 2010 and removed at the end of the 8-month trial. It targeted 90 % of households using natural gas for heating in order to secure significant gas consumption in the group (the remaining 10 % using only hot water or cooking gas). Consumers on the panel were recruited to ensure that the group was as representative as possible of the French gas customer by means of a detailed questionnaire sent by post.

By joining the panel, customers agreed to:

- Receive regularly, by post or e-mail, reports showing developments in their consumption of natural gas in different units of measurement and involving varying time units.

Table 1. Energy efficiency improvement measures.

ENERGY EFFICIENCY IMPROVEMENT MEASURES
Lower heating by 1 degree celsius
Install a thermostat
Close shutters at night
Pre-empt natural gas boiler replacement
Insulate hot water pipes
Favor showers to baths
Install aerators and water-saving faucets
Install a thermostatic mixer tap
Cover pans

Figure 3. The cities where the trials were conducted.

- Respond to three qualitative questionnaires sent during the trial in order to assess their satisfaction and demand response resulting from the provision of improved information.

Results of the field test

Every 2 weeks, and over a period of 8 months, each customer received a detailed report of its energy consumption (see Figure 6). In order to understand the type of information that maximizes customer commitment, the degree of detail as well as units of measurement would evolve weekly over a 30- to 60-day period. Time units ranged from monthly aggregated data to daily consumption information. Consumption was first displayed in cubic meters (i.e. in the same unit as the information visible on the meter), then in kWh (i.e. energy that is charged to the consumer) and finally directly in Euro.

The same set of questions was sent 3 months after the start of the trial, then 3 months after that and then 2 months later. The questionnaire was aimed at assessing developments in consumer *energy reflexivity*: their understanding of their energy use, changes in consumption patterns they declare and their willingness to implement energy efficiency improvement measures.

The questionnaires sent in December 2010 and March 2011 (79 % response rate) show an overall 83 % satisfaction rate regarding smart gas meters and related services. As a reaction to the simple availability of their energy use information, 26 % of customers announced that they were considering taking action to reduce their energy consumption (13 %) or had already done so (13 %). Figure 7 shows the measures customers had already implemented.

Moreover, this trial enabled GrDF to refine its understanding of the expected level of service. Accordingly, it has been noted that the most popular unit of information was financial: overall, there was a higher number of customers “very satisfied” with the service among those who received their statements in Euro (21 % very satisfied) than among those who received their statements in cubic meters or kWh (14 % very satisfied). Besides, changes in time units increased the overall satisfaction rate: customers switching from monthly aggregated consumption to daily aggregated consumption were more satisfied than the average customer. Finally, it appears that the way consumption information was sent (by post or e-mail) was not a differentiating factor: customers want to be able to choose according to their habits and preferences.

Our methodology uses the above findings to assess the number of consumers that will implement EIM in France and transfer our findings to general population. Since we wanted to assess the lower boundary of achievable energy savings, we adopted the conservative hypothesis that only 13 % of residential customers would take action (as mentioned before, 26 % claimed they would implement EIM). In other words, taking GrDF trials findings into consideration, the task force supposed that at least 13 % of the households would react to an improved information about their gas consumption by implementing EIM, which distribution would be similar to the results shown above. From this point, we were able to produce the matrix listing each EIM, its average impact per use per household, its penetration rate and its duration limit.

For instance, we can consider the EIM “investing in thermostat” in Table 2.

THE SECOND PILLAR CONCERNS ADDITIONAL SAVINGS BROUGHT ABOUT BY PAID INNOVATIVE SERVICES

Market research conducted by the French energy service companies showed that extra savings should be generated by services such as a “one shot” consumption diagnosis (average estimated price of 3 Euros) or a detailed consumption audit (average estimated price of 50 Euros). These are paid services to be developed by service suppliers and will rely on meter data provided by the gas network operator. Some utilities already consider such advanced services as the keystone of their future marketing strategy.

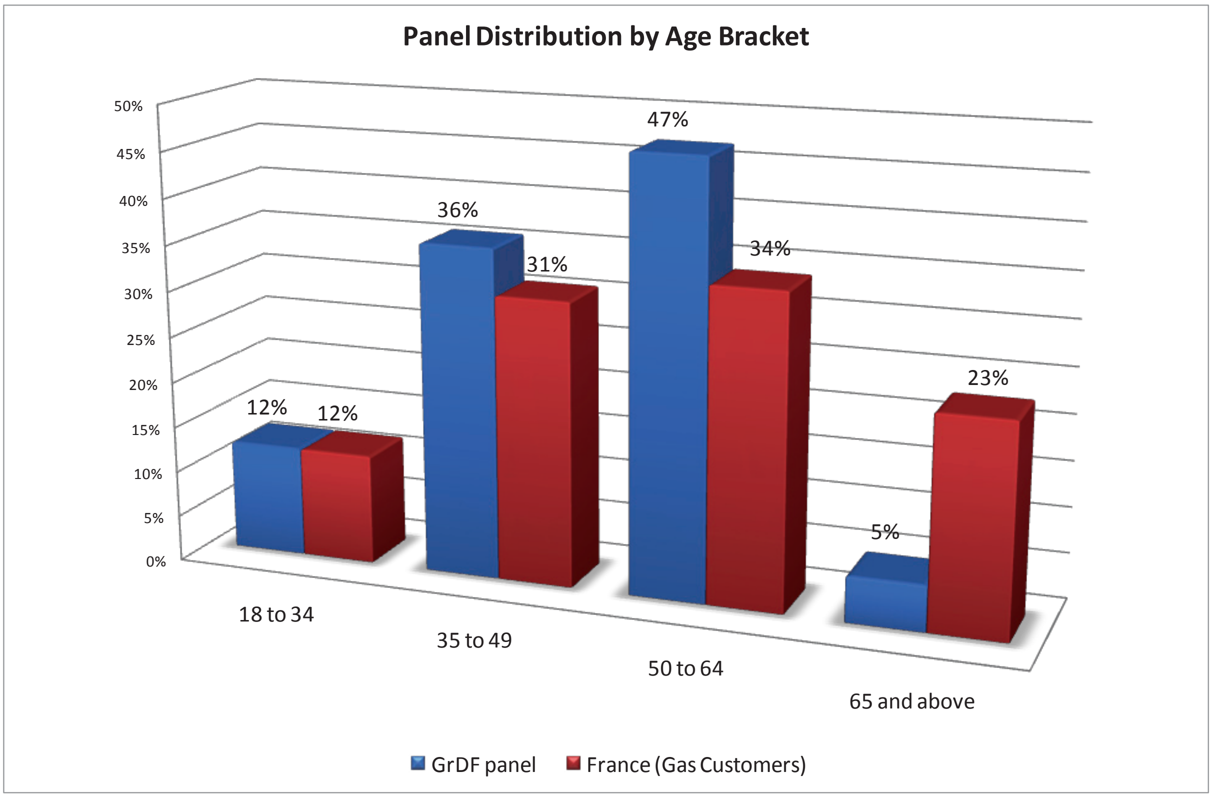

Figure 4. Panel distribution by age bracket. The age distribution shows a diversity of profiles with polarization occurring under 65 years of age compared to the average distribution for French gas consumers. "Age of the household" refers to the age of the person who represents the household.

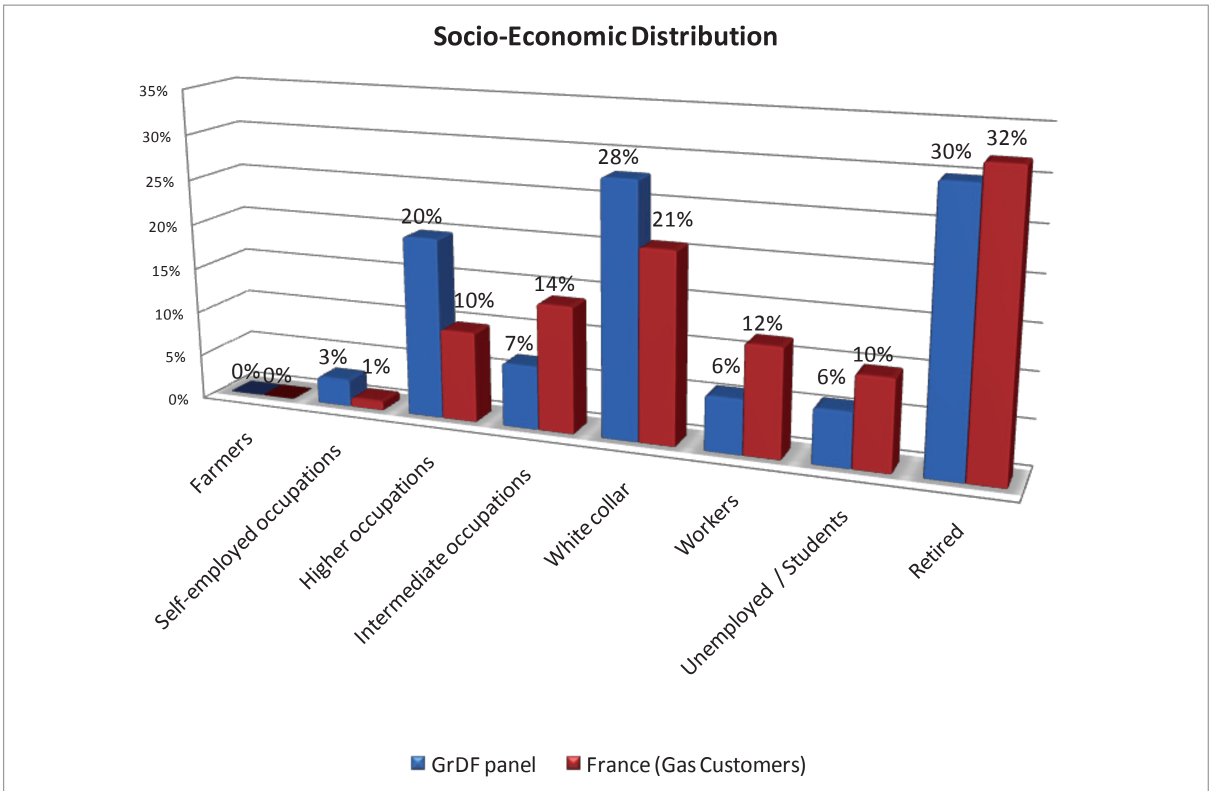

Figure 5. Socio-Economic Distribution. Compared to French gas consumers, we see a polarization of the "Higher occupation" and "White collar" categories, with an under-representation of "Intermediate Occupations", "Workers" and "Unemployed".

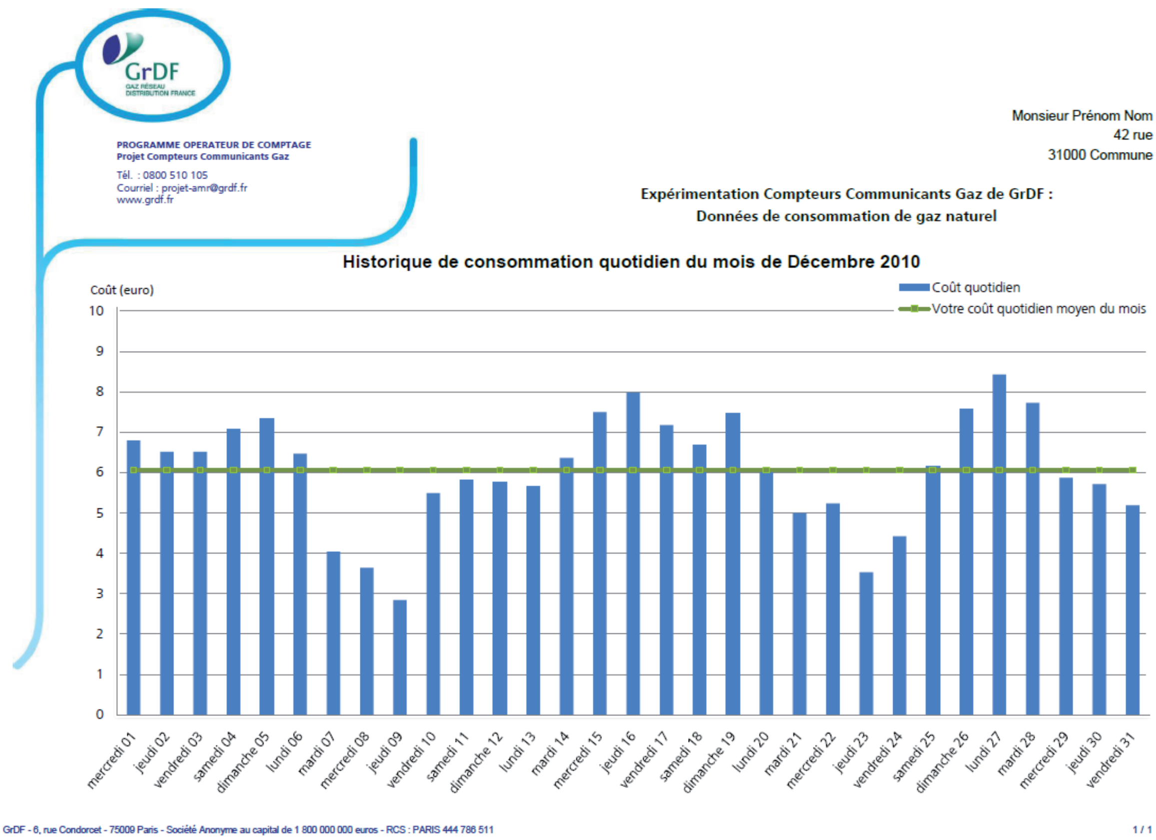

Figure 6. Example of a detailed report sent to customers on the panel (daily consumption in Euros).

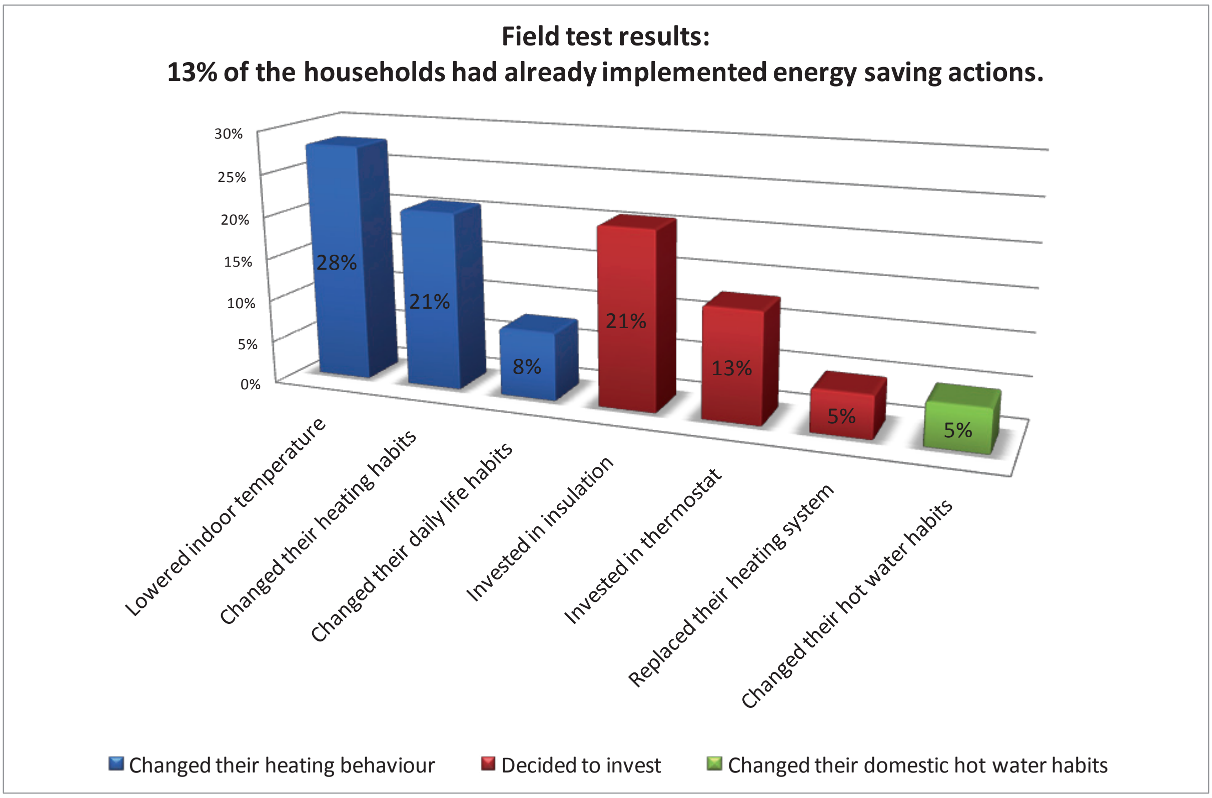

Figure 7. Field test results.

Table 2. EIM "investing in thermostat".

The White Certificate provides us with a average impact of – 1.6 MWh per household each year.
13% of the households that had implemented EIM declared having installed a thermostat. Therefore, the resulting penetration rate is the following: *13% of households [reacting to improved information] * 13% of households [investing in thermostat] =* ***1.7%*** *of households [equipped with a smart gas meter that invest in thermostat]*
The White Certificate provides us with a duration limit of 15 years for this EIM.

		ENERGY EFFICIENCY IMPROVEMENT MEASURE	USE IMPACTED	AVERAGE IMPACT per Household	RESULTING PENETRATION RATES	DURATION LIMIT
RESIDENTIAL	1	Lower heating by 1 degree celsius	HEATING	-5%	7.4%	-
	2	Install a thermostat		-1.6 MWh/y	1.7%	15 years
	3	Close shutters at night		-1%	7.4%	-
	4	Pre-empt natural gas boiler replacement		-1.4 MWh/y	0.7%	3 years
	5	Insulate hot water pipes		-2%	2.7%	-
	6	Favor showers to baths	DOMESTIC HOT WATER	-10%	0.7%	-
	7	Install aerators and water-saving faucets		-5%	0.7%	-
	8	Install a thermostatic mixer tap		-5%	0.7%	-
	9	Cover pans	COOKING	-5%	0.7%	-

		ENERGY EFFICIENCY IMPROVEMENT MEASURE	USE IMPACTED	AVERAGE IMPACT per Household	RESULTING PENETRATION RATES	DURATION LIMIT
TERTIARY	1	Lower heating by 1 degree celsius	HEATING	-7%	17.1%	-
	2	Install a thermostat		-	-	15 years
	3	Close shutters at night		-	-	-
	4	Pre-empt natural gas boiler replacement		-	-	3 years
	5	Insulate hot water pipes		-	-	-
	6	Favor showers to baths	DOMESTIC HOT WATER	*N/A*	*N/A*	-
	7	Install aerators and water-saving faucets		*N/A*	*N/A*	-
	8	Install a thermostatic mixer tap		*N/A*	*N/A*	-
	9	Cover pans	COOKING	*N/A*	*N/A*	-

Sources: White Certificates, ADEME, GrDF trial findings

Table 3. Paid innovative services.

		PAID INNOVATIVE SERVICES	USE IMPACTED	AVERAGE IMPACT per Household	RESULTING PENETRATION RATES
RESIDENTIAL	10	Consumption diagnosis	HEATING	-2%	3.6%
	11	Consumption audit over a longer period of time		-2%	2.5%

		PAID INNOVATIVE SERVICES	USE IMPACTED	AVERAGE IMPACT per Household	RESULTING PENETRATION RATES
TERTIARY	10	Consumption diagnosis	HEATING	-5%	3.6%
	11	Consumption audit over a longer period of time		-2%	2.5%

ROOFING: CONSOLIDATED ENERGY SAVINGS GENERATED BY PILLARS 1 & 2

By consolidating findings from foundations, pillars 1 and 2, and by taking residential and small tertiary gas consumption forecasts and smart metering deployment planning into account, we are able to generate a forecast of energy savings associated with the GAZPAR project. From 2022 onwards, when 100 % of *GAZPAR* smart meters will be deployed, the lower boundary of achievable savings is -0.9 %, which is around 1 TWh every year compared to the current GrDF consumption forecast shown in Figure 8.

Discussion

It appears clearly that gas smart meters are an essential tool in supporting energy efficiency policies which cannot achieve their full potential merely by relying on equipment and building efficiency improvements. *Energy reflexivity* is a key in customer commitment towards the implementation of energy efficiency improvement measures. The starting point is informing customers about their actual energy consumption. The trial carried out by GrDF, the results of which have been shared with the French Energy Regulator and ADEME, made it possible to

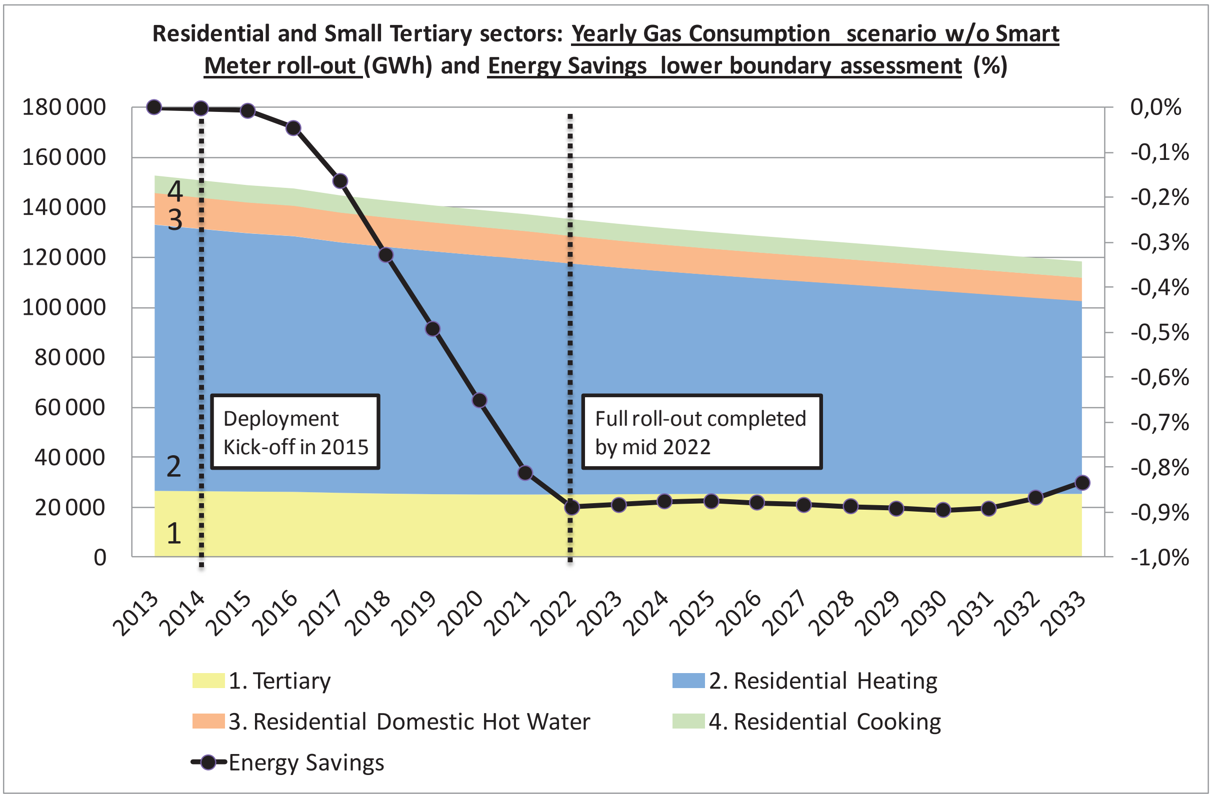

Figure 8. Consolidation of demand response patterns 1 and 2 compared to GrDF gas consumption forecast excluding benefits of smart meter roll-out. The decrease in residential gas consumption shown above is mainly due to buildings and appliances energy-efficiency improvement.

set a lower boundary of 0.9 % savings in gas consumption that would be triggered by *GAZPAR*.

Nevertheless, this field test aimed at achieving several targets which included, among others, working with all stakeholders in defining the future French gas smart meter specifications. Even if evaluation of the minimum savings that could be expected was successfully conducted, there are biases to be dealt with and sociological shortcomings.

Firstly, since gas smart meters were installed in 2010 and removed at the end of the 8-month trial, it was not possible to carry out analysis of historical data and persistence of effects. The task force relied on findings from other European trials to address these issues. The ERDP project shows that some aspect of the experience of getting a smart meter itself prompts a reduction in energy consumption, particularly gas consumption (savings of around 3 %). "The clearer effect of gas consumption makes sense in the context that simple one-off changes (e.g. reducing a thermostat setting) can have big effects on gas demand". According to the report, this effect may require support over time from other interventions (e.g. advice or billing information) to be sustained beyond fifteen months. Since energy efficiency and advanced feedback appears to be key success factors of future B2C marketing strategy of utilities, customers might experience a positive emulation and a certain level of continuous improvement in the feedback provided.

Besides, the composition of the panel shows a polarization towards households where the authority figure is under 65 years of age and GrDF was not able to challenge what respondents claimed they did during the declarative survey. A 2011 study carried out by TNS SOFRES shows that individuals aged under 54 are more interested in accessing details about their energy consumption (65 % against 54 % on average). Therefore, without being able to control actual EIM implementation, we might have a bias towards the interest shown by recipients into the questionnaire and consumption reports provided.

In order to secure the assessment, the decision has been taken to divide by two the percentage of customers willing to implement EIM: the 13 % conservative hypothesis (instead of 26 %) was adopted. Moreover, the European project *Showe It* aimed at studying the socioeconomic acceptability of a smart metering and graphic interface system, highlights some preexistent negative or critical representations of smart metering technologies in France, partly associated with the *Linky* meter. Since the electricity smart meter has sparked a great deal of controversy and discussion in the media, households might be seen to display an artificially increased distrust in the monitoring. The prudential approach of the methodology was of particular importance to make up for the panel polarization and the lack of historical data that would allow confirmation of changes in consumption patterns.

Finally, the third pillar, focusing on an additional potential for energy savings – the way consumption information would be used by third parties – has been excluded from the scope of this study. It has been deemed that available information is insufficient to develop a common understanding of the response of chosen districts or households that might participate in specific programs conducted by social landlords and local authorities. Yet, tentative results of on-going field tests in France aimed at helping households to reduce their gas consumption have shown considerable results: for instance, a 12 % decrease was achieved in yearly gas consumption within the experiment *Famille à énergie positive*. Through specific programs, not only can third parties encourage emulation among consumers, but they can also better target and devise their action-taking methods. The sociological study commissioned by GrDF and ADEME is designed to increase our understanding of household reaction to gas smart metering, wherever upgraded action and support can be provided by these local players. Results are anticipated in May 2013.

Despite the sociological biases of the trial conducted by GrDF, it appears that the prudential hypotheses adopted for this study enable us to rely on its results as the minimum benefit that might be expected by the deployment of the smart meter. This original and forward-looking approach, combining different results and strategies, shows how the task force based itself on agreed-upon data and methods in order to define an established lowest possible limit of energy savings that would be triggered by *GAZPAR*.

It appears, the actual net value of an average decrease in gas consumption of 0.9 % in the residential and small tertiary sectors makes it possible to offset the cost of investment involved in the deployment of 11 million smart gas meters in France. The model developed allows highlighting of the minimum behavioural changes that would justify an overall roll-out. The expected changes seem achievable for at least two reasons. Firstly, improved information will be provided to consumers at no additional cost, although subscribing to improved services could increase savings. Secondly, energy improvement measures do not require radical changes in daily habits: in the residential sector, the installation of a thermostat or a 1 °C decrease in the indoor temperature, if adopted by less than 10 % of users, would be sufficient.

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