Consumer Feedback Systems:
How Much Energy Saving Will They Deliver and for How Long?

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ABSTRACT

In order to foster investments in energy efficiency and also a sustainable use energy it is important to offer to consumers an effective feedback on their energy consumption coupled with other information, e.g. historical consumption or comparison with similar households, etc. that may help consumers to change their behavior and/or invest in energy efficiency technologies.

Feedback systems could be based on billing with the provision of information on the past consumption and/or on comparative information; energy consumption based on billing could also be posted on internet and social media. For consumers with smart meters real time energy consumption information could be provided on internet or through dedicated devices and displays, including mobile devices. There is also the possibility, through connected devices and appliances, even if not connected to a smart meter, to provide real time energy consumption information which may allow a prompt response from the final energy consumers and increase energy savings.

The paper proposes a taxonomy of feedback systems for energy consumption with focus on the residential sector and include some innovative examples. Based on an exhaustive literature review of research on evaluation of different feedback systems, the paper proposes a meta-analysis in order to evaluate the energy savings of the different types of feedback systems, including the persistence of the savings. Finally the paper proposes some regulatory options to introduce cost-effective feedback systems for residential energy consumption.

Introduction

Among the actions to improve energy efficiency and induce energy savings in recent years through the understanding of the importance of consumer behavior (from individual psychological and social norm points of view) researchers, utilities and policy makers have focused their attention on energy feedback. The use of this mechanism has also been enhanced by the diffusion of smart meters and the internet.

Energy Feedback is a way to turn a resource, energy, that until recently was more or less invisible to energy consumers into a visible one, creating the possibility of shifting energy consumers from a passive state into an active one. This change of paradigm makes it possible to achieve energy savings thanks to the actions stimulated from the collected and processed energy consumption information and the consequent action from the consumer, when the consumer is properly engaged.

Ultimately there are two types of Feedback: Indirect and Direct. Under these two broad categories of feedback it possible to identify some sub-categories, allowing different types of interaction and response from the energy providers and energy users. Table 1 - Types of Feedbackproposes a classification of feedback systems.

Table 1 - Types of Feedback

Type of Feedback	Sub-type of Feedback	Medium	Type of information	Communication
Indirect feedback	Standard Billing	Paper	- Historical Energy consumption - Historical comparison	One way communication
	Enhanced Billing	- Paper - Electronic environment (e-bill)	- Energy consumption, rewards - Energy Efficiency Advice - Social comparison - Historical comparison	One way communication
Direct Feedback	Direct feedback with IHD	- In-House Display - Web environment	- Real-time information - Social comparison - Historical comparison	One way communication
	Direct with Connected Devices	- In-House Display - Web environment - Smart Meter	- Real-time information - Appliance disaggregation - Social comparison - Historical comparison	Two-way communication

Indirect Feedback Systems are the most common systems accessible for energy consumers, consisting in energy feedback provided after the consumption. Indirect Feedback may be divided into two different sub-categories:

Standard billing: common energy bills belong to the first sub-category of Indirect Feedback and are usually provided by the energy retail supplier or distributor. This type of feedback is usually only describing the amount of energy consumed for a determined period of time through a paper bill or in an electronic format providing little additional information. The frequency of billing as well whether the bill is based on real consumption (meter reading) or assumed consumption (calculated on the basis of historical consumption)[1] are important elements in relation to consumer engagement. For example by paying the same amount throughout the year irrespective of real consumption may discourage energy savings.

[1] Traditionally in Europe meter reading was done once or twice a year and intermediate billing was based on estimated consumption based on previous year consumption and adjusted in the bill following the meter reading. With the introduction of smart meters all bills are based on metered consumption. Billing in Europe is usually bi-monthly.

Standard billing is the least effective type of feedback and does not motivate consumers to reduce energy consumption or invest in energy efficiency. The type of information in a typical energy bill does not go much further than the presentation of the cost (e.g. energy, distribution, power), type of tariff and in some jurisdiction a comparison with a similar period of time. This type of feedback, besides informing the final consumer to pay the bill, does not present a call for action in any way. It is only informational and non-engaging. In some countries, the lack of clarity in the bill is noticeable, leading to confusion and lack of interest.

Enhanced billing: the second sub-category of Indirect Feedback relates to both the utility bills with additional info (e.g. comparison with energy consumption in the previous year/month) and a third-party-provided indirect feedback of utility (metered) data. Still depending on measured energy consumption, this type of feedback is sometimes provided by an independent company that analyses the information collected by the utility and provides feedback providing historical and/or social comparison and context

The second type of indirect feedback category may be associated with the energy bill or not, and is provided through mailings and/or through a web. The type of information in these advanced indirect feedback systems is more elaborate than common bills, with some third-party companies using a variety of data sources besides utility data, like assessor parcel maps, home audits or census or weather data. Statistical data is commonly used by third-party companies that develop algorithms to analyze existing data and user input to provide a more personalized experience for the user. The amount and quality of information is then much richer with household information and advice, web-based energy audits and billing analysis being given. Behavioral principles are also being used in order to engage energy consumers. Tools using gamification principles like social norms and comparisons, goal setting, personal comparison and call-to-action measures are commonly used in these types of feedback systems.

This type of Enhanced billing has been being developed in recent years with success. Several companies (eg. OPOWER) working with utilities base analyses in social science and data processing. Combined with user-centric design these tools are then used by the utilities to communicate more effectively with their customers, for customer retention and/or as part of energy efficiency programmes.

This way of communicating with the client, presents energy performance to costumers in an easy way to read and understand. Descriptive and injunctive norms are used to motivate and reinforce positive behavior change as the customer can see where he/she stands in comparison with their neighbors and receive immediate gratification in the form of an emoticon (e.g. ☺). The same applies for goal setting where the customer is pursuing a specific goal and more likely to act accordingly.

Besides the common moment to communicate with the costumer, these companies choose other key opportunities for engagement throughout the year. Some of these moments rely on smart meter availability, while others can utilize traditional meter technologies. For example, a communication might be sent to the consumer in order to adapt their household for the arrival of a new season, often with advice on technologies to implement or simple behavioral changes to be incorporated in the daily life. Other type of moments can be when a high bill is expected to come, on a peak day, on a possible rate change or in the case of extreme weather or outage.

Direct feedback can be divided into the following sub-categories:

Direct Feedback using a web connected devices, where the user can log-in from a computer, tablet or smart phone, or can run an apt to have real time information on energy consumption, appliances on, historical consumption, as well as emergency messages and prompt.

Direct Feedback using In-Home Displays (IHD) where a device is installed in the home environment allowing the energy user an access of real-time information on the energy use, allowing energy users to learn about the consumptions of different appliances by turning on and off the home devices, receiving immediate appliance-specific feedback. These devices can give information on the energy use in terms of cost and can be also associated to a web environment providing extra information allowing for alarm setting and goal tracking, if the user wishes.

Direct feedback with "Connected Devices" and Automation is the most complete and engaging type of feedback before a fully automated system. To reach an accurate and effective feedback system, the user needs to have their home connected to a central device or web application, being able to control remotely at an appliance level the functionalities of the home, while having the ability even to receiving pricing signals and utility load control. These types of systems include several features and components, usually installed by the user. Examples include in-home energy displays, smart thermostats, smart plugs and smart lighting and appliances.

Companies like Plottwatt or Bidgely provide direct feedback to costumers directly or through utilities in a B2B model, being able to give information up to the level of domestic appliances. When integrated with a smart meter, these feedbacks enhance demand response potential.

Analysis of Meta-data studies on Feedback

In order to quantify the effect of feedback on energy consumption, a large number of studies have been carried out in the past 40 years. In this report we refer to the experiences already summarized in recent literature review papers, and in particular to those of E. Zvingilaite and M. Togeby (Zvingilaite, 2015), and B. Karlin, J. F. Zinger, and R. Ford (Karlin, 2015). These reviews analyzed past empirical studies on consumption feedback through qualitative methods of literature review, in which a set of empirical experiences on a specific topic are collected, classified, and summarized. Doing this task, these authors applied some inclusion criteria to ensure that the studies included in their analysis pass at least a minimum standard of quality (e.g. by excluding studies that did not have a control group as well as those with clear confounding variables).

In this way we collected a final dataset of 118 feedback applications, which cover:

- 3 consumption types (electricity only, electricity and heating, heating only);
- 16 different Countries (mainly in North America and North Europe);
- 2 feedback types (direct and indirect);
- 6 media types (bill, card, In-House-Display (IHD), mail, PC or web, mixed mode);
- A large range of sample sizes (from about 10 to almost 100 000 households);
- Different duration periods (from 2 weeks to 3 years).

Feedback Studies Breakdown

Some of the main characteristics of 118 studies are that the majority (57%) of studies have been carried out in North Europe (mostly in UK and Scandinavia) and more than one third (37%) in North America (USA and Canada); Large part of studies (58%) focused on the electricity consumptions. Also the effectiveness of feedback on heating consumption has been well documented; Possibly due to increased political focus on energy efficiency and massive rollout of smart energy metes and online services by energy utilities, the number of studies has increased during the last decade - 41% of considered studies have been carried out after 2010; Half of studies included between 100 and 1000 households; 82% of experiences have had duration greater than 3 months; The majority (59%) of studies focused on indirect means; The most represented categories of feedback frequencies are those of 1-4 times/week and continuous feedback (generally with an In-House-Display), respectively at 35% and 32% and Direct feedback was most often performed using In-Home-Displays (IHDs), while several different media (but mostly by bill and mail) were used to provide indirect feedbacks

Achieved Savings through Feedback

Both theory and past empirical research suggest that feedback may have a key role in engaging users in residential energy conservation by making consumers aware of the energy impacts of the household behaviors. However, analyzing and comparing the past literature, it is important to remark again that the considered studies have various designs, focusing on different energy consumption types and applying different methodologies. As such, the effectiveness of a feedback strategy varies based on both how and to whom it is provided. For this reasons it is not trivial to draw conclusions by analyzing and comparing the energy savings observed. However, some general indications can be obtained by classifying and categorizing the results according to contextual and methodological characteristics.

Savings per consumption type and geographical area of the studies. Firstly it is interesting to observe that the main energy savings (around 20%) were recorded on electrical consumption, independent of location. When feedback was also applied to heating consumption, the differences between North EU and North America are more pronounced: In the USA a maximum of 19% was obtained, compared to 10% in North Europe (i.e. Norway) as can be seen in Figure 1: Maximum, minimum and average savings per consumption type and geographical area. White average bullets refer to dataset composed by few studies (i.e. ≤3).

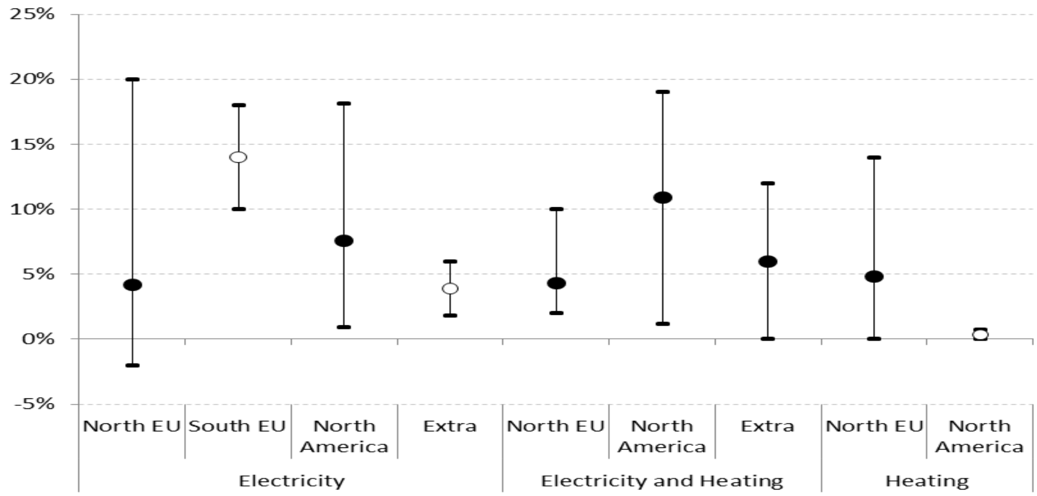

Figure 1: Maximum, minimum and average savings per consumption type and geographical area. White average bullets refer to dataset composed by few studies (i.e. ≤3).

Savings per consumption and feedback type. By grouping the achieved results per consumption and feedback type (figure 6), we can observe how generally a higher average savings is associated with direct feedback as compared to indirect. This is true when the feedback is applied on the electricity consumption (7% versus 5%) and on combined electricity and heating (9% versus 7%), but this is not the case for the feedback on heating alone. In this case both maximum (14% versus 12%) and average (5% versus 4%) savings are higher for indirect feedbacks.

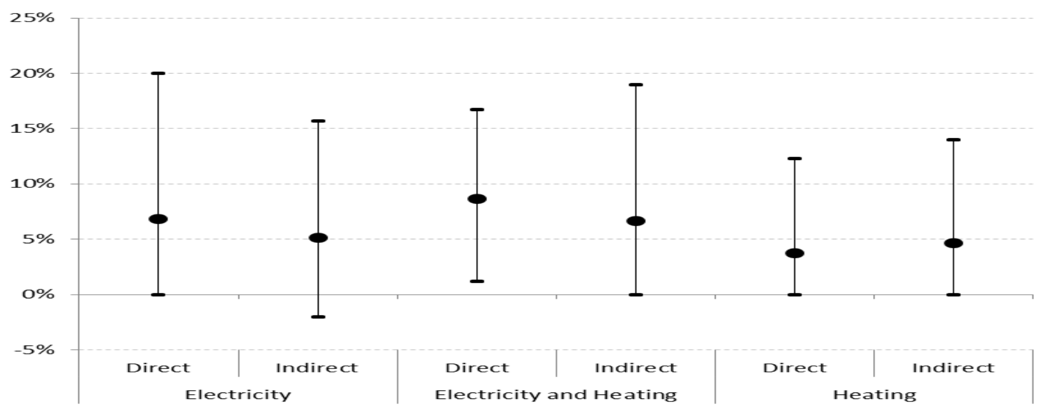

Figure 2: Maximum, minimum and average savings per consumption and feedback type.

Savings per consumption type and the period of the study. As shown by Figure 3 it is quite evident how the average savings depend on the year of the studies. As the common sense would suggest, the feedback effectiveness is related (inversely) to the grade of awareness of building occupants: in other words, the feedback is more effective in presence of a less conscious behaviour by the users. Assuming that awareness is increasing over time, this could explain that for all consumption types the average savings before 1990 are greater than those recorded after 2010. Also the fact that appliances and buildings in general tend to be more efficient can explain this decrease.

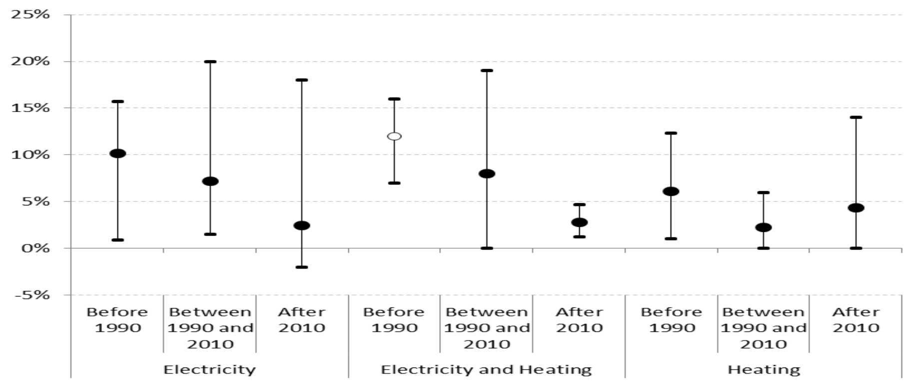

Figure 3: Maximum, minimum and average savings per consumption type and the period of the study. White average bullets refer to dataset composed by few studies (i.e. ≤3).

Savings per feedback type and medium. As far as media are concerned, this analysis reveals that maximum savings are achieved with continuous direct feedback provided by an IHD and that the indirect feedbacks provided with card (e.g. door hanger or other card/sign provided to the household by the researchers) are more effective than those provided by other means. The strategies using bills are certainly more replicable and can be extended to higher sample (see Figure 5), but their effectiveness seems to be minimal (4% in average and 10% maximum).

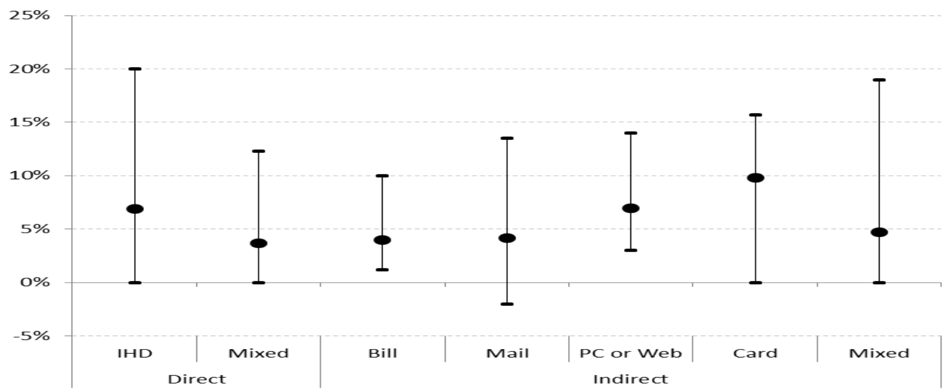

Figure 4: Maximum, minimum and average savings per feedback and medium type.

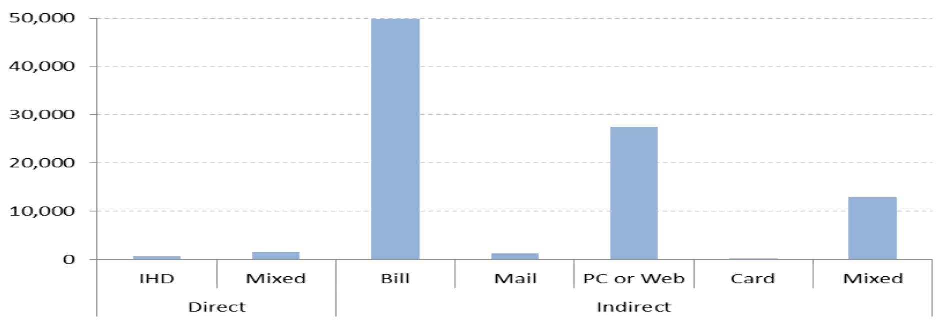

Figure 5: Average number of samples per feedback and medium type.

Looking forward, the average time spent interacting with computers and smart devices will likely increase. In the future, internet-based interactive feedback will have more opportunities to engage users for longer or more frequent periods of time. This suggests that digital media may increase feedback effectiveness. A more specific discussion is needed on what type of technological medium can/should be chosen over another, since interactivity may change depending on the type of medium - for instance, an IHD requires active user interaction to deliver feedback versus push notifications on smartphones require minimal user intervention to deliver guidance.

Savings per feedback type and frequency of interaction. Theory suggests that frequent feedback is more effective than infrequent feedback (because it helps link actions with consequences) and this is generally confirmed by Figure 10. The average savings obtained with indirect feedbacks are proportional with frequency and the absolute maximum saving has been observed with a continuous feedback provided by IHD. In accordance with previous studies, immediate feedback (the occupant is able to refer to the feedback directly after taking action) is particularly effective during a learning phase, when the user's attention is focused on specific action goals.

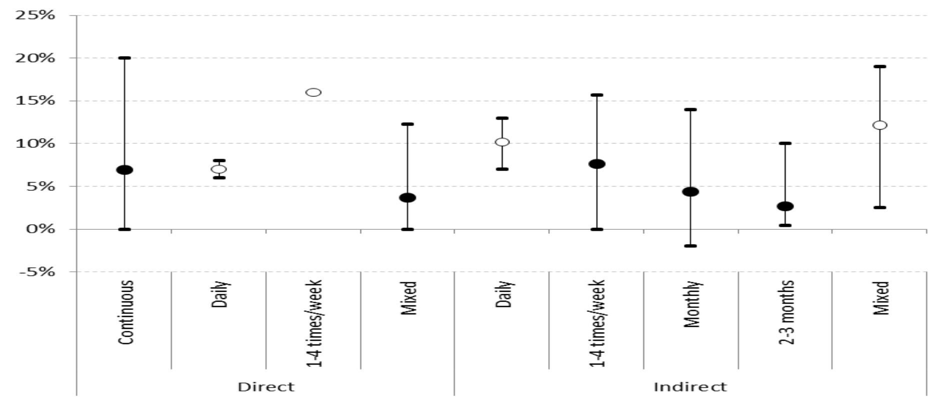

Figure 6: Maximum, minimum and average savings per feedback type and frequency of interaction. White average bullets refer to dataset composed by few studies (i.e. ≤3).

Savings per feedback type and duration of the study. Another variable influencing the effectiveness of a feedback is its persistence, i.e. the duration over which feedback is provided. Over time, occupants' attention may shift as they move from initial task learning to the satisfation of an accompished goal. Thus, the duration over which feedback is provided may impact how the feedback message is interpreted and where the users' attention is subsequently directed. Data shown in Figure 7 suggests that the average energy savings decrease with increasing duration, both for direct and indirect feedback. The fact that for short-term studies are achieving larger energy savings may be explained to a natural consumer engagement from the interest gained in the beginning of the studies, which may fade away further in time.

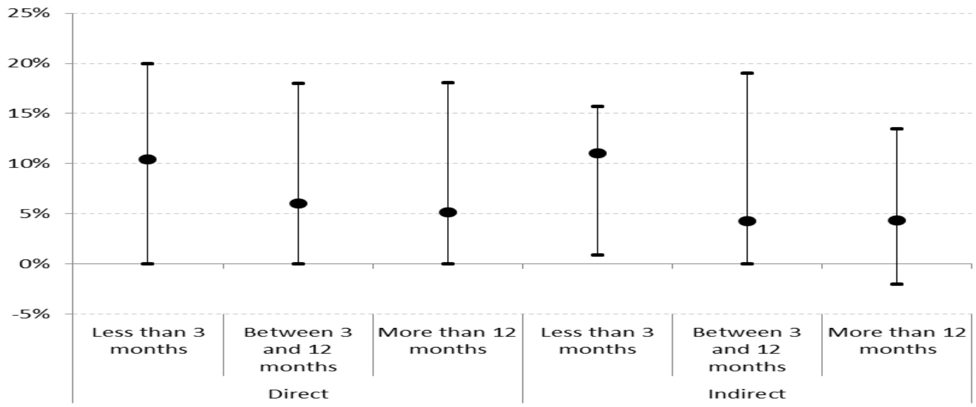

Figure 7: Maximum, minimum and average savings per feedback type and duration of the study.

Conclusions

The reviewed literature finds that feedback can reduce the households' energy consumption up to realistic 5 to 10% and that it works best when it is:

- tailored to the end-user;
- presented clearly and engagingly;
- accompanied by advice for reducing energy consumptions;
- delivered regularly and with high frequency;
- made through enhanced billing versus standard billing;
- in the presence of In Home Devices, Web Based, interactive and digital (there is a research question on the effectiveness of IHD versus a web-based display (PC, tablet or smart phone);
- capable of providing information by appliance (even if cases are still rare);
- associated with a well-defined and challenging goal (social norms).
- Direct feedback, especially when it comes to electricity consumption

However, there are relevant uncertainties from the literature and significant gaps still remain in our knowledge of the effectiveness and cost benefit of feedback. In particular:

- the effect of feedback on consumers in different social and demographic groups;
- the effect of feedback on appliance purchasing decisions;
- whether feedback continues to work over time or whether it needs to be renewed/reshaped to keep householders engaged and maintain any conservation effects.
- the ability for feedback to facilitate the sharing of energy information between households, friends or neighbours is almost entirely unexplored;
- the divergence of cost-benefit calculations for feedback with advanced metering infrastructure needs to be explored as does the conditions under which the costs of feedback outweigh the benefits.

Although awareness of energy consumption has been increasing throughout the years, proactive actions towards final energy consumers' awareness of their energy consumptions and actions on how to improve their energy efficiency and/or energy saving behaviour present themselves as a potential effective way to reduce energy consumption.

It is important that the engagement of the final energy consumers is constant in order to minimize the novelty aspect of a new way of energy feedback fading away after some time.

Two-way communication from the energy provider and final energy consumers is recommended. Gamification and social norms tools such as the comparison with similar energy consumers or the sense of gratification when the consumer's energy performance improves and is communicated towards the final consumer may offer a good solution for the continuous engagement of consumers.

The frequency of the feedback moments is another crucial point in terms of the continuous engagement of final energy consumers. While too many feedback moments may become a nuisance for the final energy consumers, a balance between too many and too few feedback moments should be studied and considered.

Considering evidence from the evaluated studies that a higher frequency of feedback leads to greater energy savings, it may be considered that the consumption readings (at least once a year) and the billing info (twice a year) currently mandated in the EU provisions should be increased for enhancing energy savings.

The smart meter roll-out in Europe is now progressing in most countries. The potential of enhanced feedback associated with smart meters, suggests that an even more attention should be given to the implementation of smart meters across Europe. The results of this meta-study analysis is a clear proof of this, with the direct feedback through IHDs presenting the greatest savings.

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