Ea Energy Analyses

Impact of Feedback about energy consumption

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1 Sammenfatning

Energieffektiviseringsdirektivet peger på feedback om energiforbrug som en metode til at fremme energibesparelser. Traditionelt er målerne for el, varme og vand blevet aflæst en gang om året. Årlig information kan være vanskelig at knytte til den konkrete adfærd.

Fjernaflæste målere gør det overkommeligt at præsentere mere detaljerede energiforbrugsdata, fx forbruget per måned, dag eller time. Feedback om energiforbrug kan ske via særlige in-house-displays, via papir, hjemmesider, SMS eller smartphones. Feedback sker typisk med en vis forsinkelse, fx hvor de nyeste informationer er 1-3 dage gamle, men kan også være i realtid.

Feedback kan inkludere sammenligninger, som kan hjælpe med at vurdere forbruget. Fx kan der sammenlignes med eget forbrug året før, eller med sammenlignelige forbrugere. Selve informationen kan være i energienheder eller i kroner. Energienheder (kWh, GJ, ^oC, m^3) kan for mange være vanskelige at forstå. Energieffektiviseringsdirektivet fremhæver faktureringsoplysninger, dvs. de samme oplysninger som faktura, men uden betalingsanmodning.

Effekt af feedback

Der er i dette projekt identificeret 24 studier og 15 review- og andre analyser. Der er stor variation i såvel i typen af feedback, som af kvaliteten af studierne. På tværs af studierne vurderes det at feedback kan forventes at give besparelser i størrelsen 2-3%. Se tabel 1.

Er informationen baseret på selv-aflæsning af målere er det vanskeligt i praksis at opnå en frekvens med månedlig eller kvartalsvis feedback. Det kan forventes at føre til en lavere besparelse, omkring 1-2%.

Besparelserne synes at kunne opnås for alle energiarter, herunder el anvendt til andet en varme og el, fjernvarme eller naturgas anvendt til varme.

Formen for feedback og den medfølgende information har betydning for den forventede effekt. Hjemmesider, som brugeren selv skal huske at bruge, har ofte en lav benyttelse. Flere studier peger på at evt. støtteinformation skal være enkel og handlingsorienteret – og hellere jævnlige korte information end mere omfattende informationer, som kun leveres en enkelt gang.

	Elektricitet	Elvarme	Naturgas/Fjernvarme
Real-time			
Antal studier, alle/bedste[1]	14/5	5/1	9/4
Besparelse, alle	0-18%	1-17%	0-8%
Besparelse, bedste	1-7%	2%	1-8%
Besparelse, median, bedste	5%	2%	2%
Indirekte feedback			
Antal studier, alle/bedste	25/9	11/4	15/6
Besparelse, alle	-2-10%	0,4-13%	0-14%
Besparelse, bedste	-2-5%	3-10%	1-7%
Besparelse, median, bedste	2%	4%	4%
Alle			
Antal studier, alle/bedste	39/14	16/5	24/10
Besparelse, alle	-2-18%	0,4-17%	0-14%
Besparelse, bedste	-2-7%	2-10%	1-8%
Besparelse, median, bedste	2%	3%	3%

Tabel 1. Overblik over resultater

[1] De bedste studier er de studier som har den bedste design, og som har modtaget score 3, baseret på kriterier for en god studie som beskrevet i afsnit 6.1.

2 Introduction

Ambitious 2020 energy and climate change goals were adopted by the European Council in 2007. The 2020 objectives include reduction of greenhouse gas emissions by 20%, increase in share of renewable energy to 20%, and to reach 20% energy efficiency. These targets were later reconfirmed in the Europe 2020 Strategy.

In 2010 forecasts showed that the 20 % energy efficiency target would not be met. Therefore there was a need for new measures at European and national level. In 2012 the Energy Efficiency Directive (EED) was adopted in order to accelerate the progress and ensure that the ambitious targets are met. The directive sets a common framework to promote energy efficiency and includes a number of measures for more efficient energy use at different stages of the energy chain – production, transportation and final consumption.

Article 10 of the directive describes measures, related to final energy consumption and billing, and distinquishes between accurate billing, billing information and consumption information. Accurate billing refers to billing, based on actual energy consumption during the billing period, as opposed to billing, based on previous year's consumption for the same period. Billing information, provided to cosnumers, must include the information on how much they will be billed for the energy they have used during the last period. In other words, the main difference between billing and billing information is that the former includes payment obligation, whereas the latter does not require payment, but, otherwise, includes the same information. Consumption information should include actual historic consumption data, which corresponds to the intervals for accurate billing or billing information, detailed consumption data according time of use, and, where relevant, comparison with normalised consumption within the same user category.

Article 10 requires Member States to ensure that consumers with smart meters are provided with accurate bills as well as access to additional consumption information, including historic detailed consumption data. Furthermore, consumers with traditional (non-smart) individual meters should be provided with frequent billing information[2]. Thus, the directive seeks to ensure that energy consumers across Europe receive feedback on their energy consumption.

Theory suggests that providing better information on energy consumption (feedback) may be effective and have an impact on consumers end-use behavior. However, the empirical evidence, found in literature, demonstrates significant differences in effectiveness of feedback on energy consumption. A

[2] Where technically possible and economically justified

large number of experiments of feedback have been conducted world-wide. These experiments use various information strategies, including providing consumers with consumption information of varying detail regarding end-uses and time of use, historic and real-time consumption, benchmark information etc. Additionally, some experiments provide energy efficiency advice and even energy audits in order to increase the effect of feedback. Regarding billing and billing information, the studies test the effects of different options – more frequent billing, information on actual energy prices (e.g. time-of-use tariffs) or other type of cost information[3].

This report includes review of the available literature, which reports the results of different field studies, conducted in order to test effects of feedback on energy consumption. The studies analyse the effects of different feedback types with respect to energy type, information, feedback frequency etc. The purpose of the review is to examine the published studies and, based on the rigor of the methodology used, conclude on the effects of different feedback strategies.

The report includes a short introduction to different types of feedback on energy consumption in section 3. Section 4 introduces Article 10 of the Energy Efficiency Directive. Methodology of a good feedback study is discussed in section 5, where the criteria for evaluating the reviewed studies are also described. Finally, the results of the literature review and the observed effects of different types of feedback are presented and discussed in section 6.

[3] Not necessarily corresponding precisely to billing information

3 Types of feedback

Households' energy use is invisible to the users and people tend to have only a vague idea of how much energy they are using for different purposes and how they can affect energy consumption by changing day-to-day practices.

Theory suggests that feedback on energy consumption can be a tool in increasing consumers' understanding of energy consumption and learning how to control ones energy use. Feedback can serve as a self-teaching tool, which also improves understanding and effectiveness of information and advice on energy efficiency in general (Darby, 2006).

Feedback is often considered as an instrument to reduce energy consumption. However,insight in the real costs of some energy services could also lead to examples of increased demand. A lagre amount of conducted studies testing different types of feedback report mixed results. Some find that provided feedback leads to significant energy savings, while others observe no significant effect or increase in energy consumption for some consumer segments. Results of the field studies depend largely on design of a study and the methodology of data analysis (see section 5).

3.1 What is feedback

A standard energy bill has little information value. Time-wise it is remote to the actual consumption event, and it also lacks the detail which would allow a better understanding of energy consumption and relating it to everyday practices.

Feedback: *Information about the result of a process or action that can be used in modification or control of a process or system… especially by noting the difference between a desired and an actual result.*

Box 1 Definition of feedback. Oxford English Dictionary adopted from Darby, 2006.

Feedback on energy consumption contributes to the building up of knowledge about use of energy. As a result, people may take in the information about energy consumption, change their behaviour and gain understanding of the effect of the behavioural change by interpreting the received feedback, see Box 2 (Darby, 2006). In this way, increased feedback may be correcting a market failure, caused by imperfect information.

INCREASED FEEDBACK → INCREASE IN KNOWLEDGE→INTENSION OF CHANGE IN BEHAVIOUR →CHANGES IN ENERGY-USE BEHAVIOUR→CHANGE IN CONSUMPTION

Box 2 Possible effect of feedback on consumption. Based on Darby, 2006.

Change in energy consumption, achieved through feedback can be persistent, when individuals develop new habits and/or when feedback has urged to invest in f.x. new appliances (Darby, 2006). Continuous feedback over a longer time-period allows people to monitor the impact of changes in their behaviour, housing and appliances, which is important for learning to use energy more effectively. Thus, persistent feedback can be important for achieving persistent changes in energy cosnumption.

Most of the international feedback studies base their reasoning of achieved energy savings on the above description of feedback and the mechanisms behind the changes in energy-use behaviour. However, the mechanisms behind the residential demand response is still not fully understood. Some literature reviews (Faruqui et al., 2010) raise questions about the value and impact of the information, provided by feedback, as compared to the impact of increased feedback merely as a reminder to save energy.

Nonetheless, most studies conclude that both information quality, frequency and persistence of feedback are important elements for achieving significant impact on energy-use behaviour.

3.2 Types of feedback

There are different types and aspects of feedback and the choice of which is important for achieving the wanted impact on consumption of different energy types: direct/indirect feedback, aggregation level of consumption information, technology/media used, timing, frequency and persistence of feedback, synergies with other type of information, comparison with historic or reference consumption etc.[4]

Direct feedback

Direct feedback is the immediate (real time) and easy accessible consumption-feedback from, for instance, an in-house display monitor or a clearly visible energy meter[5]. It is particularly useful for illustrating the moment-to-moment impact of end-use devices, like an oven or tumble dryer. Direct feedback can

[4] Based on (Darby, 2006) and ESMA (2007)
[5] However, it can, depending on a meter, be difficult to understand the information, displayed on a meter and information can be impractical for feedback purposes, e.g. in kWh and not DKK.

also be given by so-called 'ambient devices', which by light or sound can inform consumers about their energy consumption level. By direct feedback measures energy consumption information is available for the consumers all the time. Nevertheless, the effect of the direct feedback depends on how regularly consumers read the information. An initial interest may not last for years. On the other hand, it takes time for consumers to develop new energy consumption practices, thus the effect of feedback on energy consumption can be increasing during the first couple of years.

Indirect feedback

Indirect feedback is feedback, which has been processed in some way before the user receives it. Consumers have no direct access to actual consumption data (besides the accumulated energy count shown on the meter) and can only respond to previous consumption behaviour. This means that there is a time-delay between energy consumption and the moment feedback reaches consumers. The delay may be a day (e.g. if meters are read each night) or longer. In some case, more time is needed to verify the data.

Indirect feedback can include analysis of data, collected over longer period, and thus is more suitable for showing longer-term effects, such as increased insulation, home extensions, new members of household etc. The effect of indirect feedback depends on how frequent the feedback is available for consumers. In general, studies find that frequent feedback has a higher impact on energy consumption behaviour. Processing of consumption data gives the possibility to compare energy consumption with e.g. historic values, comparable consumers or other, expected, consumption.

Direct feedback	Indirect feedback
• Self-meter-reading (visible energy meter/smart meter) • In-house display • Real-time consumption on a webpage • Ambient devices	• More frequent billing • More informative frequent bills • Information on a webpage • E-mail • SMS • Energy reports by post • Self-monitoring (based on self-meter-reading)

Table 1 Examples of different types of feedback

Self-meter-reading requires a level of commitment from consumers. Nonetheless, such feedback can be effective in conjunction with information on how to save energy. The study by Winett et al. (1979) (and several other studies) has shown that consumers could quickly learn to read their own meters.

Moreover, during the study participants were taught self-monitoring, which was relatively inexpensive. The use of a (smart) meter as tool for direct feedback requires that the meter is easily accessible and easy to read.

No studies were found regarding feedback in apartment blocks, which relied on consumers self-reading the so-called *heat cost allocators* placed on each radiator[6].

Both direct and indirect feedback on energy consumption can be **disaggregated** into energy end-use (e.g. electrical appliances) giving a better understanding of, which end-uses have the highest effect on the overall energy consumption. However, such feedback can be costly, especially if disaggregation is used with direct feedback. On the other hand, consumption can also be disaggregated based on estimated values, which would lower the costs significantly. The question remains as to whether the additional information brings additional value or is superfluous (ESMA, 2007).

Time disaggregation of consumption, for instance provided by frequent billing or energy reports, and also showing energy consumption profile over time, can give a better understanding of variation in e.g. heat consumption throughout a year.

The literature emphasises the importance of **frequent feedback** in order to effectively influence consumers' energy use behaviour. As mentioned above, consumers may need time to learn about energy consumption, and identify and maintain energy conservation practices. Therefore, it is important that feedback is provided over an extended period of time. According to Darby (2006), a new type of behaviour, formed over a period of three months or more is likely to persist. Even so, **continuous feedback** is needed to help maintain the behavioural changes and encourage further changes. Some larger studies show that energy savings increase during the first and second year of feedback and become constant thereafter.

Winett et al. (1979) studies effect of consumption feedback on electricity consumption in townhouses with electric heating and claims that 'considerable savings in electricity use can accrue when feedback or monitoring procedures are implemented during seasonal peak-use periods with high-use consumers'. Thus, **timing** can also be an important factor in designing a successful feedback scheme.

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[6] In Danish: "fordelingsmålere"

Effectiveness of feedback can also be increased by combining with **other strategies**, such as energy saving goal-setting and/or rewarding for savings, and providing information on energy-efficiency measures.

4 The Energy Efficiency Directive

The Energy Efficiency Directive (25 October 2012) is meant to increase the energy efficiency in the EU – with the aim to fulfil the 2020 goal of 20 % increase in energy efficiency, compared to the baseline prediction for this year, from 2007.

Article 10 is about billing information. In article 10.1 it is required that customers without a smart meter can receive frequent billing information. "*This obligation may be fulfilled by a system of regular <u>self- reading</u> by the final customers whereby they communicate readings from their meter to the energy supplier." And "In order to enable final customers to regulate their own energy consumption, billing should take place on the basis of actual consumption at least once a year, and <u>billing information should be made available at least quarterly..."</u>*

A possible scenarios is that the customer manually reads the meter (e.g. in MWh) and send the information to the supplier. The supplier returns with billing information (in DKK). The extra information added by the supplier can include tariffs and taxes. Note that article 10.1 is about quarterly *billing information*, and that this is not the same as a quarterly bill.

Article 10.2 requires that customers with a smart meter have the possibility of easy access to complementary information on historical consumption allowing detailed self-checks. This includes historical data for the last three years and detailed data according to the time of use for any day, week, month and year. These data shall be made available to the final customer via the internet or the meter interface for the period of at least the previous 24 months.

Article 10.3 describes how third parties, like energy service providers, can get access to the data and content of the bill.

The requirements exist where this is technically possible and economically justified.

5 Design of a good feedback study

A vast number of studies have been carried out in order to quantify the effect of feedback on energy consumption. In particular, the number of studies have increased during the last decade due to increased governmental focus on energy efficiency and massive rollout of smart energy metes and online services by energy utilities. The different studies have different design, use different methodologies and show different energy saving results.

In general, the outcome of a feedback study depends on several aspects, such as, **energy type** and **technology** (e.g. smart meters), the type and quality of **feedback, design** of a study, as well as institutional and cultural background within which the study has been conducted. The most important factors are summarised in Table 2.

Design of feedback study	Risk
Sample size	Too small a sample may results in results not being significant. The smaller the impacts is, the larger sample is required
Control group or before-after comparison	With a control group the impact of general issues can be controlled for (e.g. a trend).
Participant enrolment and selection of control and treatment groups	With voluntary enrolment self-selection bias can take place. More positive people in the treatment group?
A combination of several feedbacks and other information and incentives	With several "treatments" it can be difficult to separate the impact
Duration of test	A short test period may give in-significant results (like a small sample). Long-time impact require a long observation period.

Table 2 Factors influencing results of feedback studies

Sample size has to be statistically sufficient. The energy demand in any family is varying from time to time. Without very detailed information about the household, this can be seen as a random variation[7]. The size of this variation as well as the realised savings are important in determining a good sample size. Therefore, a sufficiently large sample size is important in order to achieve significant results.

[7] E.g. in Kofoed (2013) it can be seen that the 50% of a reference group has yearly variation of the electricity consumption above (+/-) 7.5%.

Feedback studies are usually carried out either as a **controlled experiment** with treatment (those who receive the feedback) and control groups; and or a **before-after comparison** of participants' electricity consumption. With only before-and-after it is not possible to control for general change in demand, e.g. introduced by economic crises or other socioeconomic changes.

Selection/enrolment of participants and assigning them to control and trial groups can vary and can depend on practical conditions of a study. For instance, if a study depends on rollout of smart meters by a utility, only a limited segment of consumers is available for either trial or control groups. However, it is important that trial and control groups are comparable concerning all aspects, influencing energy consumption.

If it is not possible to select the participants randomly, it is important to collect information about and to account for any moderating factors and covariates such as socioeconomic characteristics, appliance stock, household size, energy prices, personal interests, etc. Often participation in such studies is voluntary and this may attract non-average people, e.g. people with interest in technology. Ideally, a stratified random sampling, which ensures that participants with different characteristics are equally represented in trial and control groups, should be used when designing a feedback study.

As for selectin of participants, a similar aspect is related to participants dropping out of the test. Again, participants dropping out may be different – maybe more negative, than the average. However, not all studies consider these aspects.

Consumer segment, chosen for the trial, can have influence on design of the trial and results of the study as well. High-energy use consumers most likely will exhibit higher energy savings, however, the savings might be casued by other reasons than feedback[8]. Larger participation can be expected from consumers with higher levels of education and income. On the other hand, consumers with higher income may be more likely to invest into energy savings measures. Some consumer groups might need to be educated on energy saving-behaviour prior to trial start.

[8] Selection of participants is likely to introduce a bias, because of the random variation of demand. Households with a high demand in a specific year are likely to use less in the next period. This is called Regression toward the mean.

Methodology, used for analysis of energy consumption data of treatment and control groups is also an important factor when interpreting and assessing the results of a study. Most studies use statistical methods to analyse the consumption results and account for possible differences between treatment and control groups or other unobserved factors, while other studies rely on a simple comparison of consumption data before and after the trial.

With random selection of control group and treatment group, and with before and after observation and sufficient large samples, the analytical procedures may be very simple. However, if selection bias exist this must be accounted for, e.g. with advanced statistical methods.

Some studies use surveys and interviews in addition to providing feedback. **Contact with participants** during a trial can influence energy consumption behaviour and affect results of the study. Particularly contact and influence of control groups can affect their energy behaviour (and this baseline) and, consequently, results of a trial. On the other hand, interviews and surveys are important in order to collect the information about participants and to be able to account for different factors, which might also have an effect on energy consumption behaviour.

The outcome of a trial also depends on **additional information given** to the participants, for example advice on how to reduce energy consumption. Some studies also include energy efficiency goal-setting by consumers as well as incentives to save energy (e.g. giving points for achieved energy savings, which can be exchange into shop-coupons).

Finally, it is important that other issues do not influence the results. E.g. if it is the impact of feedback, that is in focus, the payment for energy must have been stable in a period before the test. Else, both issues may influence the results. However, many studies combine the intervention and, therefore it is difficult to distinguish savings effect of one particular intervention.

6 Impact of feedback

6.1 The review of feedback studies

All reviewed studies (see the Appendix) are assessed with respect to the factors of a feedback study-design, presented in section 5. The review process is illustrated in Figure 1.

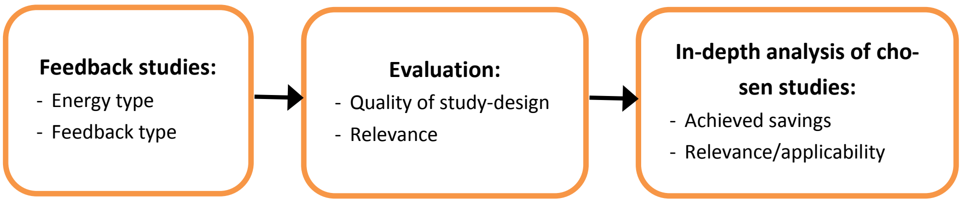

Figure 1 Steps in literature review of energy consumption feedback studies

First, the reviewed studies are sorted by energy and feedback type (direct or indirect). Three groups of feedback studies by energy type are distinguished for electricity consumption with and without electric heating, and heat consumption (gas for heating and district heating).

Further, the studies are evaluated and the best studies are identified based on the design of a study. The following criteria were used to grade the studies from 1-3, where the best studies are marked with '3' (see the Appendix):

- Duration of feedback study – min one year's duration.
- Sample size – minimum 100 participants (with some exceptions if the results are significant).
- Test design – with control group and with before and after data.
- Method for accounting for socioeconomic factors and participants' self-selection is applied in either the construction of control group or by statistical analysis of background data[9].
- Significance of results (checked for the best studies).

Furthermore, relevance of the studies with respect to the article 10 in the Directive is taken into account. Consequently, some studies are included, even though they do not include the best design e.g. studies, involving manual meter reading (self-meter-reading).The chosen studies are described and analysed more in depth, focusing on the reported energy savings, achieved during a study, as well as relevance and applicability regarding the Directive.

[9] Generally, most of the studies do not have a perfect design, particularly due to participants self-selection (i.e. possibility to opt-out) before and during an experiment. Therefore, the best studies in this review are those, which have attempted to account for or analysed this issue.

6.2 Impact of feedback – literature review

This section includes the results of the literature review. The reviewed reports and articles include either a detailed description of a particular study on energy consumption feedback, a review of conducted studies or other related discussions (see Table 3).

Literature review and other studies	Field study
Kofod (2013)	Schleich et al. (2011) a
Darby (2006)	Schleich et al. (2011) b
Vine (2013)	Carroll et al. (2013)
van Elburg, H. (2008)	Nilsson et al. (2014)
Fischer (2008)	Gleerup et al. (2010)
Buchanan et al. (2015)	AECOM (2011)
EEA (2013)	Wilhite et al. (1993)
Christiansen (2009)	Wilhite et al. (1999)
Kerr&Tondro (2012)	Winett et al. (1979)
Darby et al. (2011)	DENA (2014)
Morgenstern (2015)	ISTA (2011)
Felsmann & Schmidt (2013)	Ueno et al. (2005)
Novikova et al. (2011)	SEAS NVE (2014)
Delmas et al. (2013)	D'Oca (2014)
Vassileva&Campillo (2014)	Brandon and Lewis (1999)
	Arvola et al. (1994)
	Allcott (2009)
	DECC (2015)
	Hydro One (2006)
	Nielsen et al. (1992)
	Haakana (1997)
	HER (2012)
	Harrigan and Gregory(1994)
	Houwelingen (1989)

Table 3 The overview of the identified literature sources

A total of 39 literature sources, including 24 papers, which describe conducted field studies, and 15 review and other papers have been identified. The literature review yield 80 results[10], showing the effect of feedback on consumption of household energy consumption. The same field study usually included testing of different feedback options, which are reported as separate feedback cases in the Appendix.

Attempt has been made to describe all identified field studies/results (in the review papers or original field studies) by the following parameters:

[10] Some reports/articles describe field studies where several types of feedback (e.g. direct/indirect) or energy types are tested and analysed. Such studies yield several results. The results of the studies are therefore included and analysed as separately.

- Country
- Energy type
- Duration of a study
- Sample size
- Relation (with respect to who send and receive the feedback). Focus on examples where e.g. a meter is for an apartment block, and where indicative meters are used to divide costs on apartments.
- Use of smart meter
- Did the study rely on self-meter-reading
- Media for conveying the feedback
- Frequency of feedback
- Type (direct/indirect)
- Feedback information
- Availability of cost data in feedback (as a proxy for 'billing information', referred to in the directive)
- Use of control group
- Whether the study accounted for other factors which might influence the savings effect, such as self-selection, different characteristics of participants, weather etc.[11]
- Reported energy savings

Table 4 includes an overview of the review results by energy and feedback type and the span of the reported energy savings. In order to eliminate the outliers results are also presented as median values.

[11] Different methods were used by different studies and usually studies did not account for all possible factors, also influencing change in consumption. Therefore, in this review, at least one method applied was accepted as sufficient.

	Electricity	Electric heating	Gas/District Heating
Direct feedback			
No. of studies, all/best[12]	14/5	5/1	9/4
Savings, all	0-18%	1-17%	0-8%
Savings, best	1-7%	2%	1-8%
Savings, median, all	3%	3%	2%
Savings, median, best	5%	2%	2%
Indirect feedback			
No. of studies, all/best	25/9	11/4	15/6
Savings, all	-2-10%	0,4-13%	0-14%
Savings, best	-2-5%	3-10%	1-7%[13]
Savings, median, all	3%	4,5%	3%
Savings, median, best	2%	4%	4%
All			
No. of studies, all/best	39/14	16/5	24/10
Savings, all	-2-18%	0,4-17%	0-14%
Savings, best	-2-7%	2-10%	1-8%
Savings, median, all	3%	4%	3%
Savings, median, best	2%	3%	3%

Table 4 The overall results of the reviewed studies

Electricity consumption

Savings, as a result of feedback on electricity consumption seem to fall within a broad interval of -2 % (where consumption has increased) and 7 %. Nonetheless, when looking at the median, the resulting savings are 2 % for indirect feedback and 5 % for direct feedback. These numbers are valid for the 14 best results (out of 40). Thus, providing feedback on household electricity consumption seems to have a positive effect on savings.

The studies, showing large savings are the studies, which either have a small sample size, short duration of the study or combine several feedback options and other interventions (such as consulting, financing, possibility for remote control of electrical devices).

Indirect feedback

The indirect feedback studies included either improved information on bills or a separate feedback report, sent by post, email or available on a web-page. Several large-scale and statistically robust studies in the United States (Allcott, 2009 and HER, 2013) indicate that the effect of an energy report, sent by post

[12] Best studies are the studies with the best design, which received score 3 according to the criteria for a good study design, described in section 6.1.

[13] Here the results are dominated by fuel poor consumers and these results are likely to be affected by this bias.

or e-mail, which includes consumption information and comparison with other consumers as well as historic consumption yield between 1,5 % and 2 % electricity savings for quarterly and monthly feedback respectively. The experience showed that reports, sent by post were read more frequently than the e-mail-reports. Such feedback does not necessarily require a smart meter, but requires utilities to collect and make available consumption information at least quarterly.

The next studies all included use of a smart meter. Analysis by Gleerup et al. (2011) included possibility of frequent (daily, weekly, monthly) feedback on consumption, additional messages when consumption changes significantly and access to a webpage. Cost information was not included and results showed 2 % savings. Other feedback studies on monthly energy reports – in Germany and Austria – include a more detailed information on electricity consumption and costs over time (monthly, weekly, daily). Even more detailed information, including hourly consumption and indication of electricity consumption in different appliances was available for the subgroup (around a half of participants), who chose viewing information on a web-page instead of receiving a written feedback by post. Such feedback required a smart meter and the combination of written and web-feedback[14] resulted in electricity savings of 3.7 % to 4.5 %. The difference between the two types of studies is also that the latter included cost-information. Thus, it seems that a more detailed feedback information including costs can result in higher savings.

A feedback trial by AECOM (2011) showed 2.3% savings as a result of more accurate and informative bills including savings advice. On the other hand, another trial by AECOM (2011) of more frequent (monthly), accurate and informative bills resulted in increase in consumption by 2 % for "fuel poor" consumers segment showing the importance of the consumers for whom the feedback is targeted. Both studies included smart meters. In general, AECOM (2011) found only significant results in studies with a smart meter.

Thus, it can be concluded that indirect feedback, provided quarterly and without billing information can result in savings of at least 1.5 %. The increased frequency can only slightly increase savings (by 0.5 %). A more frequent feedback with more detailed information, including information on cost, might increase savings effect to approximately 4 %.

[14] The analysis showed no significant difference between the two feedback types and therefore results are shown for the combination.

Direct feedback
All best direct feedback studies included In-House-Displays showing real-time consumption information and cost information, as well as required smart meters. In the cases, where smart meters were not available another solution was used to read the existing meters.

In general, the studies (AECOM, 2011 and Hydro One, 2006), which included a vast amount of information including historic data, cost and environmental information as well as audible alarm if consumption increase or consumption prediction showed significant savings (5-7%). These studies also included energy savings advice. On the other hand, a recent, very robust study by DECC (2015) show statistically significant savings at 2.3 %. The feedback here included current and historic consumption and costs.

A different study by AECOM (2011) finds only 1 % savings when an In-House-Display is used in combination with a non-smart meter. Whereas another study without a smart meter (Hydro One, 2006) reports savings of 5-6.5 %. Here it can be concluded that it is reasonable to expect savings of around 2 % from direct feedback on electricity consumption through an In-House-Display, including cost information. Additional information (e.g. environmental impact) and audible or visible alarm can increase savings to 5-6 %.

Self-meter reading
Two feedback studies included consumer self-meter readings – Nielsen (1993) and Haakana (1997). Both studies relied on consumers reading their meters and sending the information every month. In study by Haakana (1997) consumers received comparative feedback about their energy costs as well as consumption relative to comparable households and historic consumption. The feedback resulted in 4 % electricity savings when compared to the group, which only read and sent meter information, without receiving any feedback. The study by Nielsen et al. (1993) did not investigate the effects of feedback, based on self-meter-reading independently but rather in a package consisting of several initiatives. Therefore, they only estimate that such feedback might lead to 2-4 % savings.

Feedback on web
Most of the studies, which make feedback information available on a web-page use it only as a supplement to other type of feedback. In general, it seems that such feedback type fails to reach the consumers, as number of web-site visits tends to be small. The study by TREFOR (Kofod, 2013) showed

savings of 3.5%. Here smart meters were rolled out and consumption information was made available on a web-page. Consumption was compared to the group of consumers who have not yet received smart meters. However, it was not investigated whether the consumption was affected by other factors.

Electricity consumption including electric heating

The results of the best studies show that feedback on electricity consumption in households with electric heating leads to savings of 2 and 3% for direct and indirect feedback respectively.

Studies that show high savings are not among the best and usually have small sample and/or a short duration as well as include goal-setting or a more detailed representation of end-uses.

The exception is the study of frequent billing and improved information on electricity bills in Oslo, where feedback resulted in 10 % (Wilhite et al., 1993). The study included a combination of increased billing frequency (from 3 times per year to every 2 months), bills, based on actual consumption as opposed to "a conto" type bills (based on previous year's bill) as well as improved information on bills (including historic comparison and advice). This combination increased consumers' knowledge of energy consumption, particularly awareness of seasonal variation in heat consumption, which lead to considerable savings. The results can be compared with those of the same study in Helsinki, where the frequent billing was a prevailing condition and the study concentrated on billing, based on actual consumption as well as consumption feedback, including historic comparison and advice. Here the achieved savings attributable to increased knowledge, were around 3 %. The study by Arvola et al. (1994), which involved a of combination of billing, based on actual consumption as well as feedback on consumption, including historic comparison in Helsinki showed savings of 3%. Those, who also received conservation advice, saved around 5%. Monthly billing combined with better consumption information and savings advise led also to savings (3%) in a study by Carroll et al. (2013)[15]. Thus, it can be concluded that more frequent and accurate bills can improve consumer knowledge, resulting in savings of at least 3 %.

Direct feedback

Smart meters were only used in two studies – both by Carroll et al. (2013). One of the studies includes an In-House-Display for showing real-time consumption, cost and tariff information in combination with bi-monthly energy

[15] This study relied on smart meter

statements (consumption by day of the week, time-of-use relative to historic consumption and other consumers, average appliance consumption levels and conservation advice), sent by mail. The study concluded that such feedback resulted in 2 % savings.

Self-meter-reading

Only two studies included self-meter-readings, however none of the results were identified as robust. Nonetheless, one of the study is worth mentioning – implementation of frequent billing (every two months) and improved consumption information, based on self-meter-reading in Stavanger (2000 consumers) indicated savings of 4 % over 2 years. However, it was not investigated whether the consumption was affected by other factors.

Feedback on web

The study by TREFOR showed savings of 4.7% for the households with electric heating when smart meters were rolled out and consumption information was made available on a web-page. However, it was not investigated whether the consumption was affected by other factors.

Consumption of gas for heating and District heating

Overall savings potential from the feedback on gas and district heating consumption seems to be 3 % for both, all and best results. The best results show savings of 2 % for direct and 4 % for indirect feedback. The best results of indirect feedback studies are dominated by the results for fuel poor consumers and therefore might be affected by this bias.

Direct feedback

The best references for the savings, achieved by the direct feedback on gas consumption (including historic consumption data) – DECC (2015) and AECOM (2011) – report savings of 1.5 % and 3.2 % respectively. In DECC (2015) feedback information includes consumption and costs, whereas trial in AECOM (2011) includes also CO_2 emissions and a "traffic light" indicator of current gas usage. Smart gas meter was used in both studies.

The study of effects of a direct feedback by Houwelingen (1989) included a display showing the daily consumption of gas as well as a reference amount, corresponding to the saving goal. The feedback resulted in 8% savings. However, the study had a relatively small sample and participant behaviour might have been affected by the energy saving goal.

It can be concluded that direct feedback of heat consumption (including cost information) can result in savings of 1.5-3% depending on the information and feedback design.[16]

Indirect feedback

Effect of indirect feedback is reported in a large study in the United States, where energy reports were sent to around 50 000 households by post or e-mail (HER, 2013). The reports include consumption information and comparison with other consumers as well as historic consumption. The study reports gas savings of 0.7 % for energy reports sent 6 times during a year. Kofod (2013) reports on results of several studies in the United States, where the same energy reports (Home Energy Report) were applied. The achieved savings span between 0.7% and 1.5 %. The energy reports do not require smart meter, but rely on consumption data available at least quarterly. Houwelingen (1989) reports 3.4% savings due to monthly feedback on gas consumption for heating. Results of this study are significant however, the sample size was small – only 50 households.

The studies by AECOM (2011), reporting effect of indirect feedback, find savings of 4 % as a result of more accurate and informative bills, and 7% due to more frequent (monthly) as well as accurate and informative bill (this result is for fuel poor consumer segment).

The conclusion can be made that monthly-quarterly feedback on heat consumption can result in heat savings of around 1-3%. If higher savings are to be achieved billing information should be included or a more frequent billing should be considered.

Self-meter-reading

Self-meter-reading has been reported in a study by Haakana (1997). The study relied on consumers reading their heat meters and sending consumption information every month. In return, consumers received monthly feedback on their consumption relative to comparable households and historic consumption as well as costs. Compared with the group that only read their meters and did not receive any feedback 4 % savings were achieved[17].

[16] According to the Danish practice for billing in district heating (with accurate billing once a year), it is not possible to provide accurate near real-time billing information. The final yearly bill includes several fees, which can first be accounted for at the end of a year.

[17] The study included relatively small sample size, short duration and possibility for self-selection bias.

Houwelingen (1989) also reports results of the self-meter-reading study. The participants were asked to fill-in a self-monitoring chart. The achieved savings were 0.8%.

6.3 Summary

Even though the reviewed studies are of varying quality and the results include a certain degree of uncertainty, it seems that feedback on energy consumption leads to changed behaviour and reduction in energy consumption. The literature review indicates that savings of 2-3 % can be achieved when considering a variety of studies with both direct and indirect feedback as well as different levels of information detail.

Article 10.1 of the Energy Efficiency Directive requires that consumers without a smart meter can receive frequent billing information[18] (at least quarterly) and suggests a self-meter reading as a possibility to collect the consumption data. The best studies, which can be related to this requirement show that frequent (quarterly or monthly) feedback on consumption can result in savings of 1-2 %, when only consumption information is included in feedback. Increased level and detail of information – time and load disaggregation, and cost information – can lead to higher (3 %) savings. More accurate and in particular frequent billing seems also to have savings effect, particularly for energy consumption for heating purposes.

Feedback, which does not include detailed information, can be provided without using a smart meter. However, it requires collecting consumption data on a more frequent basis (e.g. monthly or quarterly). Here consumers' self-meter reading can be utilised. Relying on consumers self-meter-reading in order to, in return to provide frequent feedback or billing has proved to be possible and effective, and has been implemented in billing system in Stavanger in 1996. Self-meter-reading where consumers receive a feedback in return seem to lead to energy savings (up to 4 %[19]), whereas self-meter-reading for self-monitoring purposes seems not to have a significant effect over a longer period.

Smart meters are currently being rolled out in Denmark[20] and in these cases self-meter-reading is less relevant. On the other hand, a vast majority of households, living in (existing) apartment blocks still do not have separate heating meters and so-called *heat cost allocators* (fordelingmålere) on each radiator are used to estimate heat consumption. Relying on self-meter-read-

18 Where technically possible and economically justified
19 Based on the studies without a vigorous data analysis method and possibility for self-selection bias.
20 Smart electricity meters is required for all consumers by 2020 and for district heating meters (mostly in single family houses) are rolled out by voluntary basis.

ing in this situation can be challenging, as consumers would need to read several meters (depending on a number of radiators) and the information can only be applied when information from all apartments have been collected. No studies were found regarding feedback in apartment blocks, which relied on consumers self-reading of the heat cost allocators. Nonetheless, it is reasonable to expect that savings of 1-3 % can be expected, depending on feedback frequency and included information.

Article 10.2 of the Directive requires that customers with a smart meter have the possibility of easy access to consumption information. Easy access can be provided either by an In-House-Display or information on a web-page. Use of a smart meter gives the possibility for more detailed feedback information[21] both for current and historic energy use. According to the reviewed studies, direct feedback using an In-House-Display can result in savings between 2-5[22] %.

Most of the studies, which make feedback information available on a web-page use it as a supplement to other type of feedback. In general, it seems that such feedback type fails to reach the consumers, as number of web-site visits tends to be small. The papers, that describe web-based feedback studies, report savings between 3-14 %. However, these studies either do not apply a robust data analysis method (TREFOR) or a more comprehensive information about a study (ISTA, 2011, DENA, 2014) was not available.

[21] Weekly, daily, hourly consumption and divided into different end-uses (devices)
[22] More information as well as use of audible or lighting alarms seems to yield larger savings.

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Appendix – the reviewed feedback studies

Electricity consumption

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feed-back type	Fre-quency, every	Feedback	Cost data	Savings	Signifi-cance	Media	Smart meter	Self-read-ing	Rela-tion
3	Schleich et al. (2011) a	Germany and Austria	yes	yes	12	1070	Indirect	1 month	Consumption, costs and advice	yes	3,70%	yes	Post and web	yes	no	1st
3	Schleich et al. (2011) b	Austria	yes	yes	12	750	Indirect	1 month	Consumption, costs and advice	yes	4,50%	yes	Post and web	yes	no	1st
1	Nilsson et al. (2014) a	Sweden	yes	n.a.	1	20	Direct		Consumption, costs and CO2 emissions	yes	0,00%	-	In-House-Display	yes	no	2nd
1	Nilsson et al. (2014) b	Sweden	yes	n.a.	1	13	Direct		Consumption, costs and CO2 emissions	yes	0,00%	-	In-House-Display	yes	no	2nd
3	Gleerup et al. (2010)	Denmark	yes	yes	12	194	Indirect	1 month, 1 week or 1 day	Consumption and consumption-deviation/limit alert	no	2,50%	yes	sms, e-mail, web	yes	no	1st
3	DECC (2015)	UK	yes	yes	12	5145	Direct		Consumption and costs	yes	2,3%	yes	In-House-Display	yes	no	1st
2	TREFOR a in Kofod (2013)	Denmark	yes	no	12	90000	Indirect		Consumption	no	3,50%	n.a.	Web	yes	no	1st
1	van Elburg, H. (2008) b	Italy	n.a.	n.a.	12	1000	Direct		Consumption and costs	yes	10,00%	-	In-House-Display	yes	no	1st
1	van Elburg, H. (2008) c	Nether-lands	n.a.	n.a.	24	60000	Indirect		Consumption	no	3,00%	-	Web	yes	no	1st
1	Kofod (2013), CUB	USA	n.a.	n.a.	n.a.	2457	Indirect		Informative bill, consumption, incentives, goal setting, advice	yes* (bill)	4,40%	-	Post	n.a.	no	1st
3	Allcott (2009) a	USA	yes	yes	12	23530	Indirect	1 month	Consumption and advice	no	2,00%	yes	Post and email	no	no	1st
3	Allcott (2009) b	USA	yes	yes	12	15687	Indirect	3 months	Consumption and advice	no	1,50%	yes	Post and email	no	no	1st
2	SEAS NVE (2014)	Denmark	yes	n.a.	12	276	n.a.		Time-of-use tariffs, consumption, discussion forum	yes	0,00%	no	web	yes	no	1st
3	EDF/AECOM 2011 a	UK	yes	yes	20	386	Indirect	1 month	Informative bill, consumption, cost, CO2 emissions, advise	yes* (bill)	2%	yes	Post	yes	no	1st
3	EDF/AECOM 2011 b	UK	yes	yes	20	370	Direct		Consumption, cost, CO2 emissions, advise	yes	5%	yes	In-House-Display	yes	no	1st

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Significance	Media	Smart meter	Self-reading	Relation
3	EDF/AECOM 2011 c	UK	yes	yes	20	200	Direct		Consumption, cost, CO2 emissions, advise, alarm	yes	7%	yes	In-House-Display	yes	no	1st
3	E.ON/AECOM 2011 a' (fuel poor)	UK	yes	yes	24	2639	Indirect		Accurate and informative bill, consumption	yes* (bill)	-2%	yes	Post	yes	no	1st
2	E.ON/AECOM 2011 a'' (high use)	UK	yes	yes	24	2639	Indirect		Accurate and informative bill, consumption	yes* (bill)	2%	no	Post	yes	no	1st
3	E.ON/AECOM 2011 b' (fuel poor)	UK	yes	yes	24	1436	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information	yes* (bill)	-2%	yes	Post	yes	no	1st
2	E.ON/AECOM 2011 b'' (high use)	UK	yes	yes	24	1436	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information	yes* (bill)	3%	no	Post	yes	no	1st
2	E.ON/AECOM 2011 c' (fuel poor)	UK	yes	yes	24	1456	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information and advise	yes* (bill)	-1%	no	Post	yes	no	1st
2	E.ON/AECOM 2011 c'' (high use)	UK	yes	yes	24	1456	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information and advise	yes* (bill)	2%	no	Post	yes	no	1st
2	E.ON/AECOM 2011 d' (fuel poor)	UK	yes	yes	24	2524	Direct	1 month	Frequent billing, accurate and informative bill, consumption information and advice, IHD current consumption, CO2, traffic light indicator	yes	2%	yes	Post + In-House-Display	yes	no	1st
2	E.ON/AECOM 2011 d'' (high use)	UK	yes	yes	24	2524	Direct	1 month	Frequent billing, accurate and informative bill, consumption information and advice, IHD current consumption, CO2, traffic light indicator	yes	4%	no	Post + In-House-Display	yes	no	1st
3	SSE/AECOM 2011 a	UK	yes	yes	36	2500	Direct		Consumption, cost and CO2 emissions	yes	1%	yes	In-House-Display	no	no	1st
2	SSE/AECOM 2011 b	UK	yes	yes	36	1902	Indirect	3 months	Informative bill, consumption comparison with other households	yes* (bill)	1%	yes	Post	no	no	1st
2	SSE/AECOM 2011 c	UK	yes	yes	24	524	Direct		Real-time consumption, cost, CO2, traffic light consumption indicator	yes	2%	yes	In-House-Display	yes	no	1st
2	Scottish Power/AECOM 2011	UK	yes	yes	10	1603	Direct	6 months	Consumption info and advice + IHD with Consumption, cost, CO2	yes	0%	no	Post + In-House-Display	yes	no	1st

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Significance	Media	Smart meter	Self-reading	Relation
1	D'Oca et al. (2014)	Italy	no	no	12	31	Direct		Overall consumption, consumption by different devices, on/off control	yes	18%	-	In-House-Display	yes	no	3rd (researchers)
1	Seligman et al. (1979) in Darby (2006)	USA	yes	n.a.	1	13	Indirect	1 day	Consumption	no	10%	-	n.a.	no	yes	3rd (researchers)
2	Nielsen (1992) a	Denmark	yes	yes	36	500	Indirect	1 month	Self-meter reading, consumption information, advise, financing, individual consultation, higher (50%) electricity price	no	10%	n.a.	Post, personal	no	yes	1st
2	Nielsen (1992) b	Denmark	yes	yes	36	500	Indirect	1 month	Self-meter reading, consumption information, advise, financing, higher (50%) electricity price	no	8%	n.a.	Post	no	yes	1st
2	Nielsen (1992) c	Denmark	yes	yes	36	500	Indirect	1 month	Self-meter reading, consumption information, advise, financing, individual consultation	no	7%	n.a.	Post, personal	no	yes	1st
1	Benders et al. (2006)	Netherlands	yes	no	5	137	Indirect		Web-tool with questionnaires, energy savings in % of consumption and saving tips	n.a.	9%	-	Web	n.a.	no	n.a.
2	Haakana (1997)	Finland	yes	yes	20	79	Indirect	1 month	Consumption and cost	yes	4%	-	Post	no	yes	3rd (researchers)
3	Hydro One (2006)	Canada	yes	yes	30	500	Direct		Consumption and costs, CO2emissions and outdoor temperature	yes	7%	yes	In-House-Display	no	no	1st
1	Henryson et al. (2000) in Fischer (2008)	DK and Sweden	n.a.	n.a.	n.a.	3000-4000	Indirect	1-2 months	Informative bill, consumption and advice	yes* (bill)	7%	-	Post	n.a.	n.a.	1st
1	Mack and Hallmann (2004) Fischer (2008)	Germany	yes	n.a.	n.a.	19	Indirect	1 week	Consumption	no	3%	-	Post	no	n.a.	n.a.
1	Mosler and Gutscher (2004) Fischer (2008)	Switzerland	yes	n.a.	1	48	Direct	1 day	Consumption and advice	no	6%	-	n.a.	no	yes	n.a.
3	HER (2012) b	USA	yes	yes	12	50000	Indirect	2 months	Consumption and advise	no	1%	yes	Post and web	yes	no	3rd (company)

Electricity consumption including electric heating

Quality of study (3 is best)	Study	Country	Control group	Robust data analy-sis method	Dura-tion, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Signifi-cance	Media	Smart/ meter	Self-read-ing	Relation
2	Carroll et al. (2013), A	Ireland	yes	yes	12	656	Indirect	2 months	Consumption, costs and advice	yes	0,40%	no	Post	yes	no	1st
3	Carroll et al. (2013), B	Ireland	yes	yes	12	672	Indirect	1 month	Frequent billing, Con-sumption, costs and advice	yes* (bill)	3,00%	yes	Post	yes	no	1st
3	Carroll et al. (2013), C	Ireland	yes	yes	12	636	Direct		Real-time- and bi-monthly-information on consumption, costs and advice + real time information	yes	2,00%	yes	In-House-Display	yes	no	1st
3	Wilhite et al. (1993)	Norway	yes	yes	36	600	Indirect	2 months	Frequent billing, based on actual con-sumption, consump-tion information and advise	yes* (bill)	10,00%	yes	Post	no	no	1st
1	Wilhite et al. (1999)	Norway	no	no	24	2000	Indirect	2 months	Frequent billing and consumption infor-mation	yes	4%	no	Post	no	yes	1st
2	TREFOR b in Kofod (2013)	Denmark	yes	no	12	10000	Indirect		Consumption	no	4,70%	-	Web	yes	no	1st
2	Winett et al. (1979) a	USA	yes	yes	1	12	Indirect	1 day	Consumption, goal setting, advise	no	13,00%	-	Post	no	no	3rd (re-search-ers)
2	Winett et al. (1979) b	USA	yes	yes	1	16	Indirect	1 day	Consumption	no	7,00%	-	Post	no	yes	3rd (re-search-ers)
2	Garay and Lindholm (1995) in Darby (2006)	Sweden	yes	n.a.	15	600	Indirect	1 month	Informative bill, con-sumption	yes*	n.a.	-	Post	no	no	1st
1	Dobson and Griffin (1992) in Darby (2006)	Canada	yes	n.a.	2	25	Direct		Cost data for diff. pe-riods and by end-use	yes	13,00%	-	In-House-Display	n.a.	no	n.a.
1	Brandon and Lewis (1999)	UK	yes	no	9	28	Indirect	1 month	Consumption and ad-vise	no	4,31%	-	PC	no	no	n.a.
3	Arvola et al. (1994)a	Finland	yes	yes	30	180	Indirect	1 month	Billing based on actual consumption and comparative con-sumption information	yes* (bill)	3%	yes	Post	no	no	1st
3	Arvola et al. (1994)b	Finland	yes	yes	30	173	Indirect	1 month	Billing based on actual consumption and comparative con-sumption information and advice	yes* (bill)	5%	yes	Post	no	no	1st

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Significance	Media	Smart/ meter	Self-reading	Relation
2	Hydro One (2006) b	Canada	yes	yes	30	500	Direct		In-house display with consumption and costs, CO2 emissions and outdoor temperature	yes	1,20%	-	In-House-Display	no	no	1st
2	Hydro One (2006) c (electric hot water heating)	Canada	yes	yes	30	500	Direct		In-house display with consumption and costs, CO2emissions and outdoor temperature	yes	16,70%	-	In-House-Display	no	no	1st
2	E.ON/AECOM 2011 e	UK	yes	yes	24	2524	Direct	1 month	Frequent billing, accurate and informative bill, consumption information and advice, IHD current consumption, CO2, traffic light indicator	yes* (bill)	3%	no	Post + In-House-Display	yes	no	1st

Heat consumption – gas and district heating

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Significance	Media	Smart/online meter	Self-reading	Relation	Energy Type
2	DENA (2014)	Germany	yes	no	12	145	Indirect	1 month	Consumption	no	9,00%	-	Web or Post	n.a.	no	1st	Heating
3	DECC (2015)	UK	yes	yes	12	5145	Direct		Consumption and cost	yes	1,50%	yes	In-House-Display	yes	no	1st	Gas for heating
1	ISTA (2011)	Germany	yes	n.a.	6	n.a.	Indirect	1 month	Consumption and costs	yes	14,00%	-	Web	yes	no	1st	Heating
1	van Elburg, H. a	Latvia	n.a	n.a.	12	22	Indirect	1 month	Informative bills with consumption information	yes* (bill)	0,00%	-	Post and Web	yes	no	2nd	DH
1	van Elburg, H. c	Netherlands	n.a	n.a.	n.a.	60000	Indirect		Consumption and improved data for billing	n.a.	3,00%	-	Web	yes	no	1st	Gas for heating
3	HER (2012) b	USA	yes	yes	12	50000	Indirect	2 months	Consumption and advise	no	0,70%	yes	Post and web	yes	no	3rd (company)	Gas for heating
3	E.ON/AECOM 2011 a' (fuel poor)	UK	yes	yes	24	2639	Indirect		Accurate and informative bill, consumption	yes* (bill)	4,40%	yes	Post	yes	no	1ts	Gas for heating
2	E.ON/AECOM 2011 a'' (high use)	UK	yes	yes	24	2639	Indirect		Accurate and informative bill, consumption	yes* (bill)	2,30%	no	Post	yes	no	1ts	Gas for heating
3	E.ON/AECOM 2011 a''' (not fuel poor)	UK	yes	yes	24	2639	Indirect		Accurate and informative bill, consumption	yes* (bill)	3,60%	yes	Post	yes	no	1ts	Gas for heating
3	E.ON/AECOM 2011 b'	UK	yes	yes	24	2639	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information	yes* (bill)	6,70%	yes	Post	yes	no	1ts	Gas for heating
2	E.ON/AECOM 2011 b''	UK	yes	yes	24	2639	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information	yes* (bill)	2,50%	no	Post	yes	no	1ts	Gas for heating
3	E.ON/AECOM 2011 c'	UK	yes	yes	24	1436	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information and advise	yes* (bill)	7,2%	yes	Post	yes	no	1st	Gas for heating
2	E.ON/AECOM 2011 c''	UK	yes	yes	24	1436	Indirect	1 month	Frequent billing, accurate and informative bill, consumption information and advise	yes* (bill)	2,4%	no	Post	yes	no	1st	Gas for heating
2	E.ON/AECOM 2011 d'	UK	yes	yes	24	1436	Direct	1 month	Frequent billing, accurate and informative bill,	yes* (bill)	4,60%	yes	Post + In-	yes	no	1st	Gas for heating

Quality of study (3 is best)	Study	Country	Control group	Robust data analysis method	Duration, months	Sample size	Feedback type	Frequency, every	Feedback	Cost data	Savings	Significance	Media	Smart/online meter	Self-reading	Relation	Energy Type
									consumption information and advice, IHD current consumption, CO2, traffic light indicator				House-Display				
2	E.ON/AECOM 2011 d''	UK	yes	yes	24	1436	Direct	1 month	Frequent billing, accurate and informative bill, consumption information and advice, IHD current consumption, CO2, traffic light indicator	yes	2,20%	no	Post + In-House-Display	yes	no	1st	Gas for heating
2	E.ON/AECOM 2011 d''' (not fuel poor)	UK	yes	yes	24	1436	Direct	1 month	Frequent billing, accurate and informative bill, consumption information and advice, IHD current consumption, CO2, traffic light indicator	yes* (bill)	4,90%	no	Post + In-House-Display	yes	no	1st	Gas for heating
2	Scottish Power/AECOM 2011	UK	yes	yes	9	1603	Direct	6 months	Consumption information and advice by post and IHD with consumption, cost and CO2 emissions	yes	0%	no	Post and IHD		no	1st	Gas for heating
3	SSE/AECOM 2011 c	UK	yes	yes	24	204	Direct		In-house-display with consumption, cost, CO2 emissions and traffic light indicator	yes	3%	yes	In-House-Display	yes	no	1st	Gas for heating
1	Garay and Lindholm (1995)	Sweden	yes	n.a.	15	600	Indirect	1 month	Informative bills with consumption information	yes*	n.a.	-	Post	n.a.	n.a.	n.a.	Electric heating and D
2	Harrigan and Gregory(1994)	USA	yes	yes	14	71	Direct		Consumption information + consumer education + thermostat	n.a.	0%	-	In-House-Display	n.a.	n.a.	1st	Gas for heating
2	Haakana (1997)	Finland	yes	yes	9	79	Indirect	1 month	Consumption and costs	yes	4%	-	Post	no	yes	3rd (researchers)	DH
3	Houwelingen (1989) a	Netherlands	yes	yes	12	50	Direct	1 day	Consumption and goal setting + self-monitoring	yes	8%	yes	In-House-Display	no	no	n.a.	Gas for heating
3	Houwelingen (1989) b	Netherlands	yes	yes	12	50	Indirect	1 month	Consumption information	yes	3%	yes	Post	no	no	n.a.	Gas for heating
3	Houwelingen (1989) c	Netherlands	yes	yes	12	50	Direct		Consumption information	yes	1%	yes	Meter	no	yes	n.a.	Gas for heating