Cost-effectiveness of energy efficiency programs – evaluating the impacts of a regional program in France

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ABSTRACT

This paper presents the evaluation of a regional energy efficiency program implemented in two "départements" of France. EDF provides refurbishment advices and financial incentives to end-users in the residential sector as well as specific training courses and certification to local installation contractors and building firms. Refurbishment actions analysed in this paper are efficient space heating equipment (condensing boilers, heat pumps and wood stoves or boilers), solar domestic water heating and the installation of new windows. A billing analysis based on a survey of program participants' energy consumption is used to calculate the energy savings attributed to the program. In order to receive an economic feedback of this demonstration program, the evaluation of both saved energy and program costs is of importance. The detailed knowledge of the program's cost effectiveness is essential for EDF to achieve the saving obligations imposed by the French White Certificate scheme at the lowest cost. Results of this evaluation can support the development and implementation of further energy efficiency programs with similar characteristics in other regions of France. The cost-effectiveness is determined from the perspective of the program participant and society as well as the energy company in charge of the program. Results are expressed in levelized costs of conserved energy in Euro/kWh, which allow a direct comparison with the avoidable costs of the energy supply system.

Introduction

The improvement of energy efficiency is a major task to address environmental, economical and energy security challenges. To cope with these challenges, the European Union adopted the Directive on Energy End-use Efficiency and Energy Services, which sets an indicative target to the Member States to reduce their national energy demand by 9% in the period from 2008 to 2017 (European Parliament and Council 2006). Against this background, in June 2006 France initiated a white certificate scheme that commits energy suppliers to implement demand-side energy efficiency activities and verify certified amounts of saved energy. The French white certificate scheme (FWC) is one of the main instruments to fulfill the European target (Osso et al. 2009). From 2006 onwards, EDF has conducted a regional energy efficiency program dedicated to space heating in the residential sector. Due to the pilot character of the program the evaluation of energy savings and program costs is particularly important.

Program background

The ambitious residential sector program is offered by EDF for 5 years in two "départements"[1] of France, Haute-Marne (code 52) and Meuse (code 55). EDF agreed to invest

[1] Administrative division. Population: 193,701 inhabitants in Meuse and 187,654 inhabitants in Haute-Marne (2006).

several million Euros in this region by implementing the so called MDE 52-55 energy efficiency program. The main objective of this program is to generate substantial energy savings in the residential sector to achieve the associated benefits for households such as reduced energy bills and an increased level of comfort. In order to meet this objective, EDF disseminates information of energy saving opportunities for households and provides refurbishment advices as well as financial incentives, i.e. soft loans and bonus payments to the end-users for different types of energy efficiency improvement measures. Households are provided with interest free loans if the refurbishment measures meet certain energy performance levels and with bonus payments that depend on the specific type of end-use actions. The specified performance levels of the energy efficiency measures are more demanding than the ones required for obtaining tax credits from the state. The bank Domofinance[2], a subsidiary of EDF and BNP Paribas Personal Finance, coordinates and arranges the financial support to the households. Promoted energy efficiency improvement measures are building shell improvements (roof or wall insulation, double-glazed windows), efficient space heating equipment (condensing boilers, heat pumps and wood stoves or boilers), and solar domestic water heating. In return for the achieved end-use savings, EDF is rewarded with white certificates. These certificates are used to meet the saving obligation imposed by the FWC scheme on energy supply companies (Bertoldi et al. 2010). Until March 2009, a total of 3,143 energy efficiency improvement measures were implemented that can be assigned to the MDE 52-55 program. The share of each individual type of energy efficiency improvement measure in the total is illustrated in figure 1.

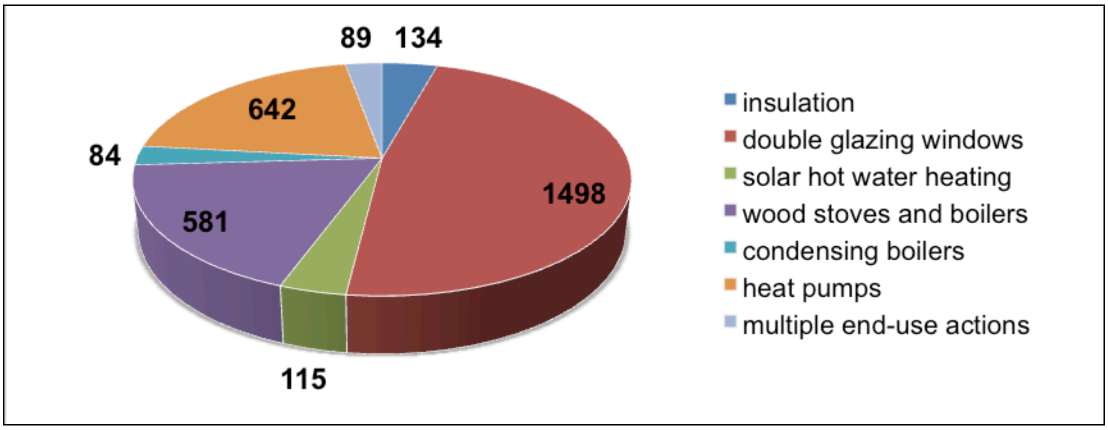

Figure 1. Number of MDE 52-55 energy efficiency improvement measures (March 2009)

A further decisive objective of the MDE 52-55 program is to strengthen the whole regional economy (Guennec et al. 2009). In the respective “départements” an excellence cluster in the field of energy efficiency is initiated by promoting the building and installation sector. In order to improve the competences of local installation contractors and building firms in the field of energy efficiency and to ensure a minimum quality standard of their refurbishment work, training courses and certification are offered. For these services, the installation contractors and building firms pay a small subscription to EDF and receive in return an agreement to implement the refurbishment actions that are promoted by EDF in the residential sector.[3] The building and installation sector benefits from an increasing demand of energy efficiency services and, therefore, generates a higher income. The “départements” Haute-Marne and Meuse benefit on the one hand from the increasing economic activity, for example through higher tax incomes and increased employment, and on the other hand from an image improvement triggered by innovative projects.

[2] http://www.domofinance.com/

[3] The agreement is assigned under the trademark “bleu ciel”, http://www.edf.fr/edf-fr-accueil/edf-partenaires-118001.html

The primary motivation of EDF to implement the MDE 52-55 program was not explicitly to achieve cost-effective energy savings in the residential sector but to initiate a pilot program as a demonstration case that is accompanied with a profound evaluation. The evaluation results will be disseminated in order to optimize the implementation conditions. A detailed economic evaluation of this pilot program is of particular importance since energy efficiency programs are the first means for EDF to achieve its saving obligations imposed by the French White Certificate scheme. Moreover, the evaluation is especially important as the program focuses on refurbishment actions that are implemented in rural regions located in the east of France. In these regions 70% of the dwelling stock is built prior to 1975, i.e. before any thermal regulation existed. In addition, 28% of the dwelling stock is still space heated with oil and 29% with wood (INSEE 1999). Such dwellings (i.e. old and oil heated) are the main target for retrofitting programs as the potential of energy savings is very large.

Calculation procedure

The evaluation of the MDE 52-55 program is mainly based on a survey that covers around 10% of all participants at the time of evaluation. The sample size of the survey of the different types of energy efficiency improvement measures is illustrated in table 1. By checking the whole sample for plausibility it turned out that a large share of the data were incomplete or implausible and, thus, had to be excluded. The lower line in table 1 presents the numbers of useful data sets that remained.

Table 1. Sample size of individual types of end-use actions

Type of end-use actions	Heat pumps	Condensing boilers	Wood stoves and boilers	Solar hot water heating	Insulation	Double glazing windows	Multiple end-use actions
MDE 52-55 program	642	84	581	115	134	1498	89
Data in survey	70	35	60	30	30	46	35
Useful data in sample	54 (47*)	19	36	22	22	36	Not evaluated

*fuel switching

Pre-retrofit and post-retrofit billing data are available in the sample, whereas action-specific technical data are not available. A billing analysis is, consequently, used to determine the savings. Beyond the overall data preparation and check for plausibility, the evaluation consists mainly of the following three steps:

1. Estimating the share of electricity and fuel consumption that is used in Haute-Marne and Meuse solely for space heating;
2. Temperature normalization of the pre-retrofit and post-retrofit energy consumption in order to avoid that weather variations affect substantially the evaluation results. The annual heating consumption of a specific year is multiplied with the ratio of year specific heating degree days (which differ between the two "départements") and normalized heating degree days of a typical meteorological year;
3. Quantification of the energy impacts: electricity and fuel (gas, oil, wood) consumption before and after the installation of the energy efficiency improvement measures are compared to each other in order to determine how many kWh per unit or participant are saved annually due to a specific end-use action. Since fuel consumption data is not expressed in kWh but in other energy units or even in energy costs (Euro/year), conversion factors are applied to allow a comparison with electricity consumption. Moreover, total gross annual energy savings are

determined by multiplying the total number of program participants with the unitary annual savings calculated in the first step for each measure type.

Unitary annual savings

The electricity and fuel consumption per participant that is saved annually due to a specific end-use action is shown in figure 2. For heat pumps and condensing boilers incremental savings are evaluated. It can be expected that in absence of the MDE 52-55 program many end-users would have installed low temperature boilers instead of the more efficient condensing boilers or heat pumps. Consequently, the energy consumption of condensing boilers and heat pumps is compared with the fuel consumption of low temperature boilers in order to determine the incremental savings. For all other measure types full savings are assessed.

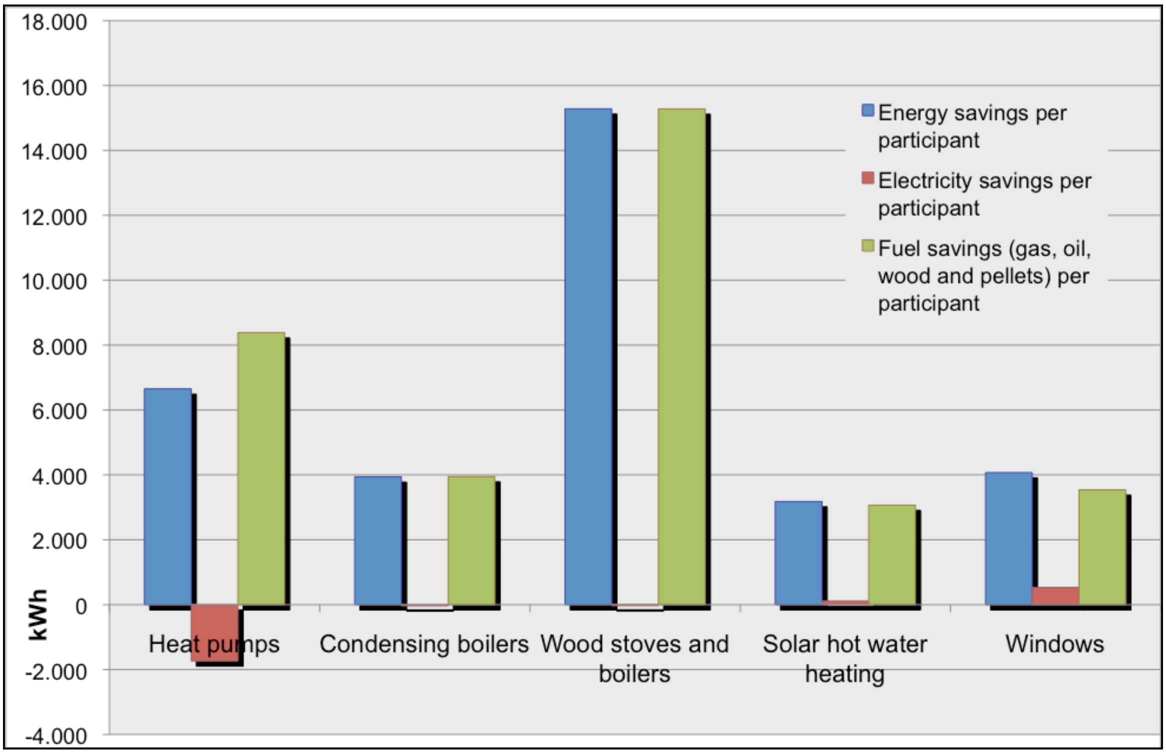

Figure 2. Annual MDE 52-55 energy savings per participant. Full savings: wood stoves and boilers, solar hot water heating and windows; Incremental savings: heat pumps and condensing boilers.

Regarding the evaluation results, it becomes apparent that pre-retrofit and post-retrofit electricity consumption only change slightly as a result of the energy efficiency improvement measures compared to the fuel consumption changes. This result is not very surprising since the share of electricity consumption for space heating is with 12.5% quite small in Haute-Marne and Meuse (INSEE 2006).

The evaluation results of heat pumps are solely based on participants who switched from fuel to electricity heating.[4] As a result, the installation of heat pumps has increased the annual electricity consumption per participant by more than 1.7 MWh. With respect to fuel savings, the highest savings were achieved by the installation of wood stoves and boilers. More than 15 MWh per year were saved on average by MDE 52-55 participants who installed efficient wood stoves or boilers. Despite the assessment of incremental savings, the second largest fuel savings were realised by the installation of heat pumps with more than 8 MWh per year. However, these fuel savings are partly

[4] The number of participants with electric heating also before the heat pump installation was too small in the sample for a representative evaluation.

absorbed by the increasing electricity consumption. Almost 4 MWh were saved by condensing boilers compared to the consumption of low temperature boilers according to this evaluation. The savings resulting from the installation of new windows are about the same level. Slightly more than 3 MWh are saved by installing solar hot water heating systems.[5]

It should, however, be considered that a direct comparison of the savings is difficult, as the results are expressed for some end-use actions in incremental savings and for other actions in full savings. Moreover, the level of pre-retrofit energy consumption differs between different types of measures. As a result, the savings of the measures with a comparably high pre-retrofit energy consumption are usually larger compared to those actions with a relatively low pre-retrofit consumption. Finally, the typology of dwellings and the household characteristics often vary strongly between different types of refurbishment actions.

The assessed savings should, in principle, be rather conservative estimates since program participants often increase their level of comfort after the refurbishment action, i.e. use their heating system more intensively because they know that energy is used more efficient. This rebound effect (Greening 2000) is included in the consumption measured after the implementation of the action by the end-user and is, thus, “automatically corrected” in the results of a billing analysis. The significance of the rebound effect has been assessed qualitatively using information about the level of the set-temperature before and after retrofitting taken from the survey: a median value of a temperature increase of +2°C is observed, albeit, with a large deviation.[6]

The degree of uncertainty of the evaluation results with respect to this billing analysis is comparably large because of the moderate sample size and due to the inability of comparing the results with a control group of similar customers who did not participate in the program (due to a lack of data). Consequently, the results of this analysis should be considered cautiously. Despite of this large degree of uncertainty, the authors believe that comparing pre-retrofit and post-retrofit (and for condensing boilers and heat pumps normal retrofit vs. post-retrofit) energy consumption more accurately reflects the real program savings than by simply taking into account the deemed savings specified for the FWC system (which would have been the alternative). Besides, using FWC deemed savings, which are expressed in kWh cumac[7], is difficult due to a different kind of calculation methodology for different types of end-use actions. Differences include the specification of the reference situation (efficiency of the stock of end-uses or market efficiency), the valuation of renewable energy using equipment and the possible consideration of the rebound effect. For these reasons, the comparison of the savings calculated with the billing analysis and the FWC deemed savings is difficult. Between some types of end-use actions, large deviations of the annual savings exist. Concluding, both evaluation methodologies appear not to be very consistent with each other, which can be partially explained by the calculation methodology of FWC deemed savings.

Gross annual program savings

By multiplying the total number of MDE 52-55 program participants with the unitary annual savings calculated in the previous section, gross annual program savings can be estimated.[8] The results in figure 3 show that three dominant measure types exist: the installation of wood stoves and boilers achieved with 8879 MWh per year the largest overall impact in terms of saved energy. Second largest gross savings are achieved with more than 6000 MWh by the installation of efficient windows due to the large number of participants of this end-use action (average savings per

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[5] Savings of insulation of walls and roofs could not be assessed with a reasonable accuracy due to a too low sample size.
[6] From -5°C to+6°C, with an average of +1.5°C (sample of 199 participants).
[7] Meaning cumulated on lifetime and discounted (4%).
[8] Gross annual energy savings are the total amount of all annual savings of MDE 52-55 program participants per energy efficiency improvement measure.

participant of windows are comparably low).[9] Third largest savings are achieved by the installation of heat pumps with more than 4,000 MWh. The installation of condensing boilers and solar hot water heating systems has contributed to the whole program savings only marginally due to the low number of program participants. By taking into consideration these results, the MDE 52-55 program generates at the time of this study in total almost 20,000 MWh of final energy savings per year. The gross annual savings should, however, not be considered as final program savings since the number of program participants is continuously rising. At the end of 2009 already more than 8,000 customers participated in the MDE 52-55 program compared to the 3,143 participants at the time of this study.

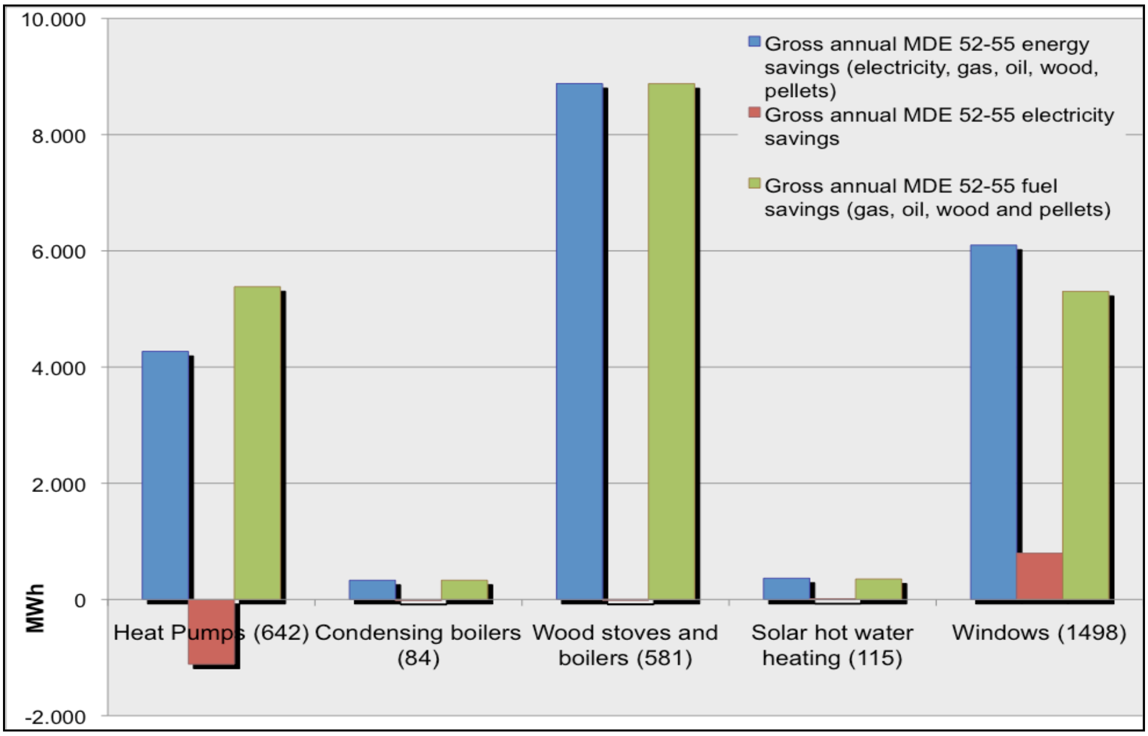

Figure 3. Gross annual MDE 52-55 program savings (insulation not included)

Gross-to-net correction factors are not taken into account in this study since no surveys regarding the free-rider and spill-over effect are available for the MDE 52-55 program. Moreover, the assessed energy savings could, in principle, be influenced by governmental incentive payments that led to further refurbishment actions not attributed to the MDE 52-55 program within the same time frame of this study. Due to the limited evaluation resources of this study the assessed savings are not corrected for double-counting and it is assumed that the free-rider and spill-over effect compensate each other. Concluding, the underlying assumption of this study is that the net savings are consistent with the calculated gross program savings.

Program costs

The cost-effectiveness of energy efficiency programs depends largely on the program costs and the specific costs of the energy efficient technologies that are promoted by the program. In order to promote energy-efficient solutions, EDF offered incentive payments to customers in the residential sector. Provided that the refurbishment actions meet specific energy performance levels,

[9] The results of gross annual energy savings should, however, interpreted with care since it is explicitly assumed that the share of electric and fuel heating in the sample and the whole MDE 52-55 program remains constant. Moreover, the fact that all assessed participants in the sample who installed a heat pump switched from fuel to electric heating should be considered when interpreting the whole program evaluation results.

households are given access to interest free loans and bonus payments in order to renovate their buildings. The level of incentive payments received by the MDE 52-55 program participants depends on the costs and specific types of energy efficiency improvement actions implemented. Figure 4 shows the average incentive payments for each type of measure received by program participants. Average bonus payments per program participant are directly calculated from the values given in the sample. The costs for EDF of providing the interest free loans are determined by calculating the net present value (NPV) of the capital income that cannot be gained anymore by EDF due to the provision of the interest free loans. These costs depend on the level and length of the soft loan and the imputed interest rate of EDF. On average, the highest incentive payments are provided to program participants that installed heat pumps. The lowest overall incentive payments are received by MDE 52-55 participants who installed windows.

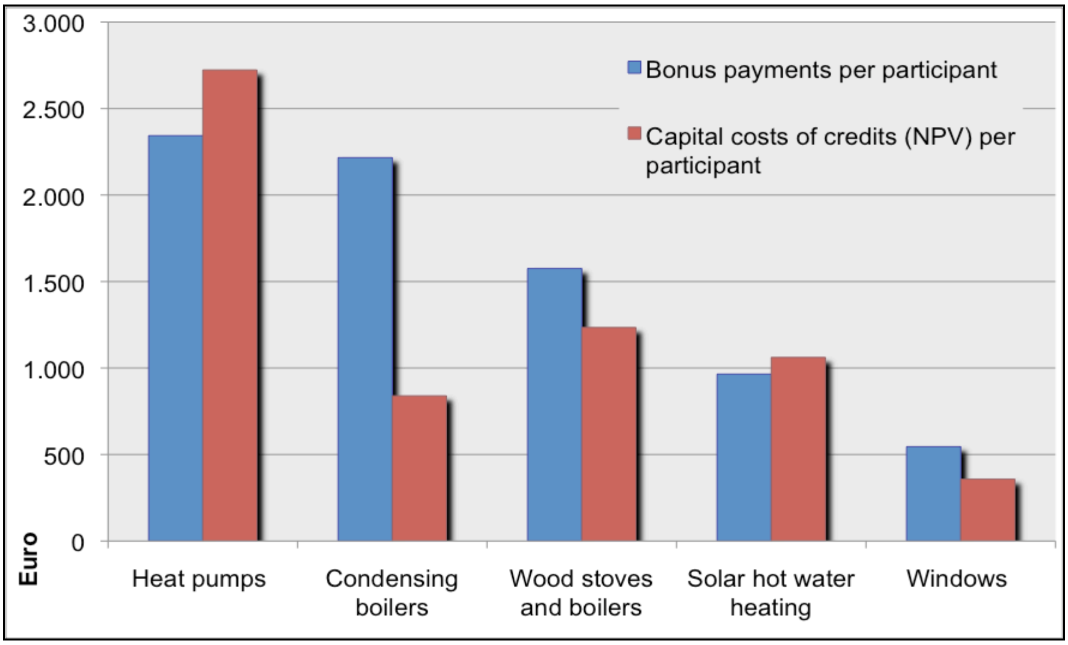

Figure 4. Incentive payments provided to program participants

Beyond incentive payments, overhead costs such as administration, labour and marketing costs are borne by EDF as the program implementer. Consequently, these overhead costs should be considered in the cost-effectiveness analysis. The specific overhead costs of the MDE 52-55 program are, however, not determined yet. Typically, overhead costs of similar programs range between 10% and 30% of total incentive payments provided to program participants. Thus, an average share of 20% of total incentive payments is specified as overhead costs in this study.

Finally, tax credits which are provided by the French government are considered in the cost-effectiveness analysis from the perspective of the customer. It is assumed that all households demanded the tax credits as the scheme is very well known by end-users in France. The specific level of tax credits provided by the state is calculated as a share of the pure equipment costs of the energy efficiency measure.

The costs of the efficient end-use action are an important cost component included in the cost-effectiveness analysis from the participant and societal perspective. Overall costs are given in the sample for each participant and type of end-use action. These costs comprise all costs that accumulate until the work is completed and include costs of the efficient technology, additional material expenses and further costs of the local installation contractors and building firms such as labour costs. Using the sample data, an average cost value for each type of end-use action is determined. For the evaluation of heat pumps and condensing boilers incremental costs are, however, relevant as it can be assumed that in absence of the MDE 52-55 program house owners would have installed low temperature boilers instead of the more efficient condensing boilers or heat pumps. Consequently, the additional savings are compared with the incremental costs in the analysis. They are determined by calculating the price difference of the efficient and the standard appliance, which are the costs of a low temperature boiler. Figure 5 shows the final customer costs of the efficient end-use action that are calculated by subtracting the governmental tax credits of the total (incremental) end-use action costs.[10]

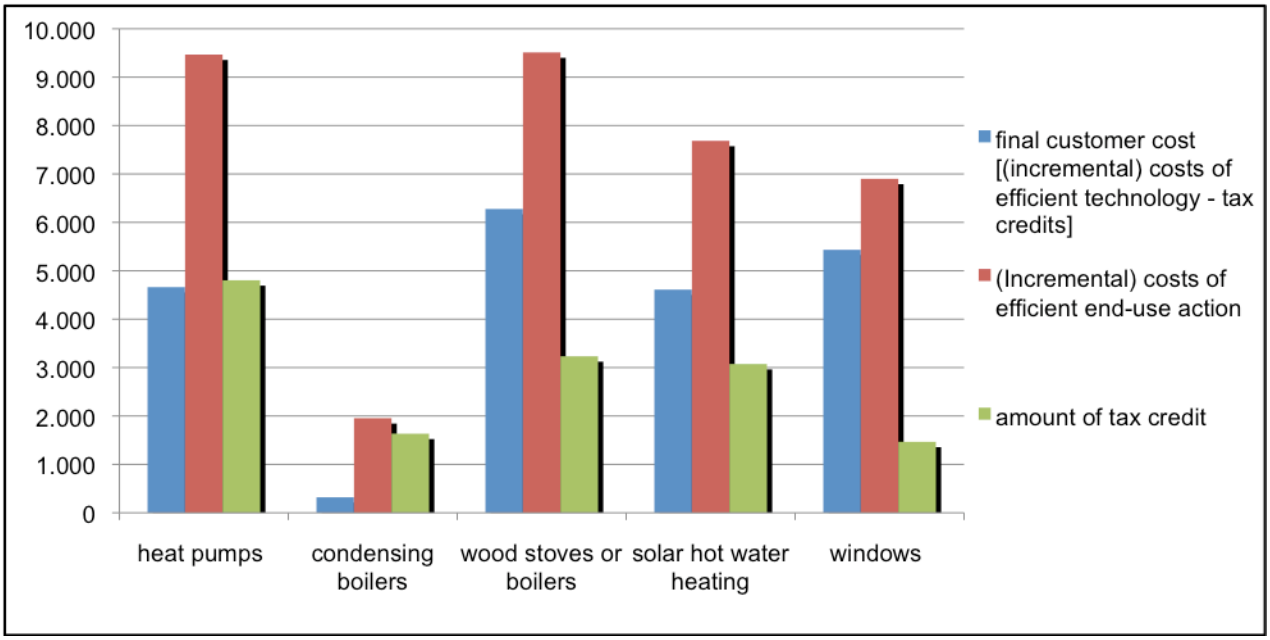

Figure 5. Average (incremental or full) costs of efficient end-use, final customer costs and amount of tax credits

Cost-effectiveness

The cost-effectiveness is determined from the perspective of the participant, the society and the energy company in charge of the program. Levelized costs of conserved energy (LCCE) in cent/kWh are chosen as the indicator of cost-effectiveness, which allow an immediate comparison with the avoidable costs of the energy supply system. For the calculation of LCCE, the cost stream of energy efficiency improvement measures is discounted using an appropriate discount rate to yield the net present value (NPV). The discount rate depends on the specific stakeholder perspective.[11] By multiplying the NPV with a capital recovery factor (CRF), the NPV is converted (levelized) to an equal annual payment. This annual cost value is divided by the annual energy savings achieved by the specific energy efficiency improvement measure to obtain LCCE in cent/kWh. The calculation is described by the following formula:

[10] The final customer costs of the efficient end-use action shown in figure 5 do not include the incentive payments and interest-free credits obtained by program participants of EDF.

[11] As three different stakeholder perspectives are assessed, a discount rate assumption for each cost-effectiveness test is necessary. The average lending rate of private individuals is appropriate from the participant perspective as it reflects the debt costs an average household would pay to finance an investment in energy efficiency. It is assumed to be 8%. The interest rate that is relevant from the energy company perspective is reflected by the weighted average cost of capital (WACC). The WACC of EDF are approximately 8%. A lower discount rate of 3% is used from the societal perspective.

$$LCCE = \frac{(NPV \times CRF)}{annual\ savings}, \text{ with } CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

i: real discount rate
n: lifetime of the energy efficiency end-use action

Table 2 compares the cost and benefit components that are relevant and possible to monetize with respect to the cost-effectiveness evaluations of the MDE 52-55 program from the three perspectives.[12] Pure qualitative impacts and costs and benefits that may be relevant in other program or energy market contexts such as cost-recovery schemes are not included in this table. The result of each evaluation provides different information about the impacts of energy efficiency programs on stakeholders. By taking the evaluation results of all perspectives into account, most information about distributional effects between stakeholders and about the appropriate level of incentive payments is provided, and the implementation of too costly programs can be avoided.

Table 2. Benefit and cost components included in the cost-effectiveness evaluation

Perspective	Benefits	Costs
Energy company - integrated electricity generation and retail supply company	Avoided energy supply system costs (wholesale prices, T&D tariffs) Additional energy sales revenue (net of taxes and T&D tariffs) Avoided penalties of the FWC scheme	Additional energy supply system costs (wholesale prices, T&D tariffs) Lost marginal revenue (net of taxes and T&D tariffs) Incentive payments to program participants (bonus payments and capital costs of interest free loans) Program overhead costs
Program participant	Energy bill savings (incl. taxes) Incentive payments (received bonus payments and avoided capital costs of interest free loans) Tax credits	(Incremental) costs of the energy efficiency improvement measure (incl. VAT)
Society	Avoided energy supply system costs (wholesale prices, T&D grid losses) Avoided external environmental costs	(Incremental) costs of the energy efficient improvement measure (excl. VAT) Program overhead costs

The program participant perspective

Energy efficiency improvement measures will be cost-effective from the perspective of the program participant, if the realised cost savings over the expected measure lifetime outweigh the costs of the specific end-use action. A benefit-cost ratio above one indicates that an end-use action is cost-effective. An evaluation from the perspective of the program participant is essential since customers will be unlikely to participate in an energy efficiency program if their benefits are lower than the (incremental) costs of the energy efficiency improvement measure. Benefits include the energy bill savings achieved by using the more efficient technology over the expected lifetime, the incentive payments provided by EDF and the governmental tax credits.

Table 3 shows the cost-effectiveness of the different MDE 52-55 energy efficiency improvement measures. The implementation of heat pumps, condensing boilers as well as wood stoves and boilers is profitable for customers since avoided energy bills, and received tax credits as

[12] A constant future energy price (average price of 2008 and 2009 for electricity and each fuel type) is assumed in this study for the calculation of energy bill savings and avoided energy supply system costs. If it is assumed that energy prices increase over time, energy bill savings and avoided energy supply system costs will be underestimated in this study.

well as incentive payments clearly outweigh the (incremental) technology costs. The installation of solar hot water heating systems and new windows is not cost-effective according to the evaluation results. The main reason is that the costs per kWh saved of these measure types are comparably high as the calculations assume that the retrofit is only done for the sake of energy efficiency. However, it is likely that, for example, old windows had to be replaced anyway. Then, the application of incremental costs and savings would be more appropriate. This was, however, not possible due to a lack of data. An additional explanation why the installation of new windows was not profitable for end-users is that program participants received less incentive payments and tax credits compared to the other measure types. Furthermore, using an interest rate of 8 % is a cautious assumption, based on the consideration that the home-owner has to take a loan to finance the investment. If he/she had no need to take a loan, the interest rate could be set at rates comparable to those available on bank accounts, so 3 % would be appropriate for the end-users' perspective as well. In this case, all the measures would be cost-effective.

The calculations have been executed also without considering the tax credits provided by the French government. All end-use actions with exception of condensing boilers are not cost-effective from the customer perspective if the governmental tax credits are neglected in the evaluation. This means that the incentive payments provided by EDF are alone not sufficient for a profitable implementation of all end-use actions promoted by the MDE 52-55 program with exception of condensing boilers.

Even if the degree of uncertainty of the evaluation is comparably large, the evaluation results support the specification of the right level of incentive payments and tax credits that ensures the attractiveness of the implementation of energy efficiency improvement measures. At the same time, the evaluation indicates if too high incentive payments or tax credits are provided for measures that are comparably profitable like condensing boilers. Moreover, taking into consideration the evaluation results helps to avoid the promotion of end-use actions like double-glazing windows with a comparably low energy saving potential and at the same time high costs.

Table 3. Levelized cost and benefit components per kWh saved and benefit-cost ratios from end-users' perspective (interest rate 8 %)

Measure type	**Heat pumps**	**Condensing boilers**	**Wood stoves and boilers**	**Solar hot water heating**	**Windows**
Lifetime	16	16	15	15	35
(Incremental) costs of efficient end-use action [Euro/kWh incl. VAT]	0.1302	0.0561	0.0727	0.2825	0.1454
Bill savings *[Euro/kWh]*	*0.0579*	*0.0640*	*0.0495*	*0.0668*	*0.0640*
Incentive payments *[Euro/kWh]*	*0.0683*	*0.0877*	*0.0215*	*0.0745*	*0.0190*
Tax credits *[Euro/kWh]*	*0.0647*	*0.0469*	*0.0247*	*0.1130*	*0.0309*
Total benefits [Euro/kWh]	0.1909	0.1985	0.0957	0.2542	0.1139
Benefit-cost ratio	1.47	3.54	1.32	0.9	0.78

Potential increases of the residential property value and comfort gains for customers due to the installation of the more efficient technology are not considered in the cost-effectiveness analysis. They are, however, an important motivation for many end-users to refurbish their home. Thus, measures that are from an economic point of view not cost-effective should not automatically lead to the conclusion that customers won't participate in an energy efficiency program. The installation of new windows is a good example that shows that energy savings are not necessarily the main trigger for customers to refurbish their dwelling. The refurbishment of windows is the measure type with the lowest cost-benefit ratio (assuming the refurbishment and all costs are borne just for saving energy) and shows at the same time by far the highest participation rate in the MDE 52-55 program compared to all other types of end-use actions.

The societal perspective

The economic impact on the entire society is measured by comparing the sum of (incremental) costs of the efficient end-use actions and program overhead costs with the avoided energy supply system costs. Moreover, the avoided external costs associated with the end use consumption of fossil fuels are incorporated as a benefit in the evaluations. CO_2 emissions from end-use consumption of fuels are not covered by emission allowances and, thus, represent external costs. The avoided CO_2 emissions are monetized by taking the carbon price of 2008 and 2009 and the specific CO_2 factors of fuels into consideration. The incentive payments provided by EDF and the governmental tax credits are not relevant from the perspective of the society as they represent transfer payments which do not create added-value. In contrast to the energy company and customer perspective, a societal discount rate of 3% is used in the calculations. The result from the societal perspective is especially relevant for energy policy as it will indicate if the whole society is better off by implementing energy efficiency improvement measures or programs. All MDE 52-55 end-use actions with the exception of condensing boilers are according to this analysis not cost-effective since the sum of avoided energy supply system costs and external environmental costs do not outweigh the (incremental) costs of the efficient end-use actions and program overhead costs. Avoided energy supply system costs and avoided external environmental costs are, however, determined by assuming constant future energy and carbon prices. Taking into consideration increasing energy and carbon prices over time would, consequently, increase the cost-effectiveness. It should also be noted again that for windows, incremental costs and savings may be more appropriate and lead to cost-effective savings, but that it was impossible to assess this case here.

Table 4. Levelized cost and benefit components per kWh saved and benefit-cost ratios from the societal perspective (interest rate 3 %)

Measure type	**Heat pumps**	**Condensing boilers**	**Wood stoves and boilers**	**Solar hot water heating**	**Windows**
Lifetime	16	16	15	15	35
(Incremental) costs of efficient end-use action *[Euro/kWh excl. VAT]*	*0.0762*	*0.0330*	*0.0436*	*0.1693*	*0.0659*
Overhead program costs *[Euro/kWh]*	*0.0043*	*0.0055*	*0.0058*	*0.0058*	*0.0032*
Total costs [Euro/kWh]	0.0806	0.0385	0.0494	0.1751	0.0692
Avoided system costs electricity and fuels *[Euro/kWh]*	*0.0223*	*0.0381*	*0.0347*	*0.0385*	*0.0390*
Avoided environmental costs from fuel emissions *[Euro/kWh]*	*0.0036*	*0.0044*	*0.0025*	*0.0044*	*0.0030*
Total benefits [Euro/kWh]	0.0260	0.0425	0.0372	0.0429	0.0420
Benefit-cost ratio	0.32	1.10	0.75	0.24	0.61

The energy company perspective

The most important driver for energy companies operating in liberalised electricity markets is to increase their profits. Therefore, the main objective for EDF is to minimize the costs of saved energy in order to fulfill its saving obligations imposed by the FWC scheme in the most cost-effective way. From the perspective of EDF, incentive payments including the provision of the bonus payments as well as the capital costs of the interest free loans are considered as a cost factor in the evaluation. In addition, the overhead costs of EDF resulting from the program implementation and lost marginal electricity revenue are considered as costs. In contrast to the numerous cost factors, only minor benefits that are reasonable to express in monetary terms are relevant for EDF since no cost recovery mechanisms exist in France. Among the monetized benefits are the contribution margin of increased electricity sales due to fuel switching of participants who installed heat pumps and more important the avoided penalties of 0.02 Eur/kWh cumac that must be paid by obliged actors of the FWC scheme in the case of non-compliance.[13] Concerning the benefit of additional electricity consumption, the calculations assume that the households remain customers of EDF. Table 5 shows that all cost-benefit ratios are smaller than one, indicating that the promotion of all MDE 52-55 energy efficiency improvement measures is not cost-effective for EDF to fulfill its saving obligations. One explanation of this outcome is that no mechanism is established in France that allows energy companies to recover energy efficiency program costs. If such a mechanism existed, all MDE 52-55 energy efficiency improvement measures would be cost-effective for EDF.

Table 5. Levelized cost and benefit components per kWh saved and benefit-cost ratios from the energy company perspective (interest rate 8 %)

Measure type	**Heat pumps**	**Condensing boilers**	**Wood stoves and boilers**	**Solar hot water heating**	**Windows**
Lifetime	16	16	15	15	35
Incentive payments [Euro/kWh]	0.0683	0.0877	0.0215	0.0745	0.0190
Overhead program costs [Euro/kWh]	0.0062	0.0078	0.0080	0.0080	0.0059
Lost marginal revenue electricity [Euro/kWh]	-0.01534	-0.00018	0.00002	0.00263	0.00969
Avoided system costs electricity [Euro/kWh]	-0.01385	-0.00016	0.00001	0.00237	0.00875
Avoided penalties of the FWC scheme [Euro/kWh]	0.0178	0.0554	0.0122	0.0111	0.0148
Benefit-cost ratio	0.38	0.58	0.41	0.16	0.68

Even if the promotion of the energy efficiency improvement measures is not cost-effective from the energy company perspective, it should not be generalised from the evaluation results that energy efficiency programs are no meaningful business strategy for EDF. It should be considered that many impacts that are difficult to evaluate in monetary terms are neglected in this calculation scheme. In liberalized electricity markets where customers are free to choose their energy supplier, a central motive of energy companies to offer energy efficiency programs is to increase their customer loyalty. Moreover, an image improvement may result in additional revenues from customers who were retained or won as new customers.

Conclusion

This paper presents the evaluation results of an energy efficiency program implemented by EDF in two "départements" of France. The cost-effectiveness of the implementation of efficient space heating equipment (condensing boilers, heat pumps and wood stoves or boilers), solar domestic water heating and the installation of new windows is determined from the perspective of the program participant and society as well as the energy company in charge of the program.

[13] In order to allow a comparison of the costs per kWh saved with the avoided penalties, the specific avoided penalties of the FWC expressed in cumac must be calculated in Eur/kWh per year and expressed in relation to the savings calculated from the billing analysis.

According to the results of a billing analysis, substantial fuel savings have been achieved in the two respective areas. The highest annual savings per participant were achieved by the installation of wood stoves and boilers and heat pumps. The installation of new windows, wood stoves and boilers as well as heat pumps generated the largest overall impact in terms of gross annual program savings. It is, however, emphasized that the degree of uncertainty of the calculated savings is comparably large due to a moderate sample size in combination with a lack of data of a control group.

The evaluation results point out that the implementation of heat pumps, condensing boilers as well as wood stoves and boilers is profitable for customers since avoided energy bills, received tax credits and incentive payments clearly outweigh the (incremental) technology costs. In contrast, the implementation of solar hot water heating systems and the installation of windows are not cost-effective for program participants. If the tax credits provided by the French government are neglected in the evaluation, all end-use actions with the exception of condensing boilers are not profitable for customers. As a result, the incentive payments provided by EDF are alone not sufficient for a cost-effective implementation of the energy efficiency end-use actions by program participants. The high participation rate of customers who installed new windows indicates, however, that an assessment of measures as ‘unprofitable’ should not automatically lead to the conclusion that customers won’t participate in an energy efficiency program. Non-energy benefits such as comfort gains and an increasing property value are an important motivation for many end-users to refurbish their home.

The economic impact on the entire society is measured in this study by comparing the sum of (incremental) costs of the efficient end-use actions and program overhead costs with the avoided energy supply system costs and the avoided external environmental costs. Since the benefits do not outweigh the cost components, all MDE 52-55 end-use actions except from condensing boilers are not cost-effective from the societal perspective. A possible explanation of this outcome is the assumption of constant future energy and carbon prices in the determination of avoided energy supply system costs and avoided external environmental costs. It should also be noted again that for windows, incremental costs and savings may be more appropriate and lead to cost-effective savings, but that it was impossible to assess this case here.

The main objective for EDF is to minimize the costs of saved energy in order to fulfill its saving obligations imposed by the FWC scheme in the most cost-effective way. In contrast to the numerous cost factors such as incentive payments and program overhead costs, only minor benefits are relevant for EDF. Among the monetized benefits are the contribution margin of increased electricity sales due to fuel switching of participants who installed heat pumps and, more importantly, the avoided penalties related to the FWC scheme in the case of non-compliance. As there is no cost recovery mechanism established in France, the promotion of all types of energy efficiency improvement measures assessed in this study with the amount of incentives provided in the MDE 52-55 program is not cost-effective for EDF to fulfill its saving obligations. The main reason for this outcome is the lack of a mechanism for EDF to recover costs. This is a unique feature of the French system of energy savings obligations: In all other countries that have energy savings obligations for energy companies, these are given the possibility to recover program costs. With such a mechanism, all the measures assessed here would be cost-effective for EDF. The authors, however, point out that even if end-use actions are not cost-effective from the energy company perspective, it should not be generalised that energy efficiency programs are no meaningful business strategy. A central motive for many energy companies to offer energy efficiency programs is to increase their customer loyalty and to improve their corporate social responsibility in order to generate additional revenues.

In 2010, a new survey will be conducted in order to strengthen the accuracy of the assessed energy savings. Moreover, avoided energy supply system costs and external environmental costs will be determined by taking into account increasing future energy and carbon prices to improve the results of the cost-benefit analysis.

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