Spending to save: evaluation of the energy efficiency obligation in Denmark

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Abstract

In 2012 Ea Energy Analyses, NIRAS, and Viegand & Maagøe, conducted the second evaluation of the Danish Energy Efficiency Obligation (EEO). The overall purpose of the evaluation was to assess the effectiveness of the EEO framework and, if relevant, provide recommendations for adjustments of the EEO framework and guidelines for the following EEO period, i.e. 2013-2020.

This paper focuses on the net savings impact and describes the evaluation method used to determine this. Three complementary analyses are described: 1) An analysis of the additionality of the reported saving, 2) an analysis of the technical accuracy of the savings reported by the obligated parties, and 3) a statistical case study focusing on net effect of heat savings in the residential sector. The evaluation results are discussed and the subsequent implementation of recommendations is presented.

The evaluation concluded that while the energy distribution companies meet their overall saving obligation, the net savings impact are about a third of the savings reported by the obligated parties. Further it was found that while energy savings in the public and business sector have a high net impact, some subsidies given under the EEO are inappropriately high. The net impact in the residential sector, on the other hand, was found to be very low. The evaluation recommended that the new EEO design addresses the additionality issues in order to ensure that savings realised in the residential sector are more cost-effective from a socioeconomic perspective.

The evaluation has resulted in noticeable adjustments of the design of the Danish EEO, e.g. introduction of a 1 year payback-time limit for projects receiving subsidies, a minimum baseline for insulation products, and specification of documentation requirements.

Introduction

Improved energy efficiency is a valuable means to improve security of supply and reduce greenhouse gas emissions in a cost-effective way thus mitigating climate change. Further, a more energy efficient economy could boost innovative technological solutions, increase competitiveness of the industry and create jobs.

In Denmark, energy distribution companies have been involved in energy savings at the end-user level since the early 1990s. Traditionally, their savings effort was limited to performing energy audits and giving advice to their customers. The framework for this activity was radically changed with the introduction of the first Energy Efficiency Obligation (EEO), operating from 2006 onwards. The EEO is based on a voluntary agreement within a legislative framework with the distributors of electricity, natural gas, and district heating. The private heating oil companies chose to commit to the EEO voluntarily. The energy distribution companies covered by the agreement will hereafter be referred to as the *obligated parties*.

With the introduction of the EEO, the saving effort was significantly restructured. The obligated parties were permitted to realise energy savings across the country, within all forms of energy and within all sectors; only transport was excluded (until 2013 when four specific, well-defined savings measures within transport were introduced). Freedom of method was in-

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troduced in 2010 with respect to the types of instruments that the obligated parties may use (for instance, allowing subsidies) as well as trading savings. The changes increased the dynamics and flexibility of the EEO market e.g. through increased competition in providing competent advice to the attractive industrial customers (Ea Energy Analyses et al. 2012).

Trading savings requires an agreement on the ownership of the savings between the end user, the obligated parties, and a possible third party before the project is commenced. After the savings have been realised obligated parties who exceed their annual energy saving target can sell the excess to other obligated parties or the savings can be transferred to the following years in the agreement period. At the end of a calendar year the deficit may not exceed 35% of the average annual target. The flexibility of the EEO market realise efficiency gains which would not be available in the absence of trading.

EEOs or tradable white certificates have been used for years in Denmark, Flanders, France, Italy, and United Kingdom. From 2013, an EEO will also be in place in Poland. So far no sector or group of companies, which have been subject to an EEO, have failed to fulfil their savings target. On the contrary, there is a tendency to overachieving (Ea Energy Analyses et al. 2012; Giraudet et al. 2012; Togeby et al. 2012b). In Denmark, the target has been raised several times, and the obligated parties are still overachieving. The Danish obligation in 2006-2009 was 2-3 times higher than the savings realised under the previous system. From 2010 the obligation was doubled, and it will double again in 2015 (see Figure 1) as a result of the political agreement of March 2012 (Political agreement 2012).

The amount of savings realised in the residential and public sectors have been fairly stable since the EEO was first introduced, whereas savings realised in industry rapidly increased as a result of the increased obligation from 2010 onwards. About 65 % of all registered saving in 2011 were found in businesses (industry or commercial sector) (see Figure 2).

The Danish EEO has thus produced significant energy savings in industry. This is in contrast to the examples from France, Italy, and UK where the residential and public sector dominate (Lees 2012). In principle, industrial projects are allowed in the Italian and French white certificate systems; however, certain requirements regarding monitoring and documentation hinder that savings are realised in any significant volume. In the Dan-

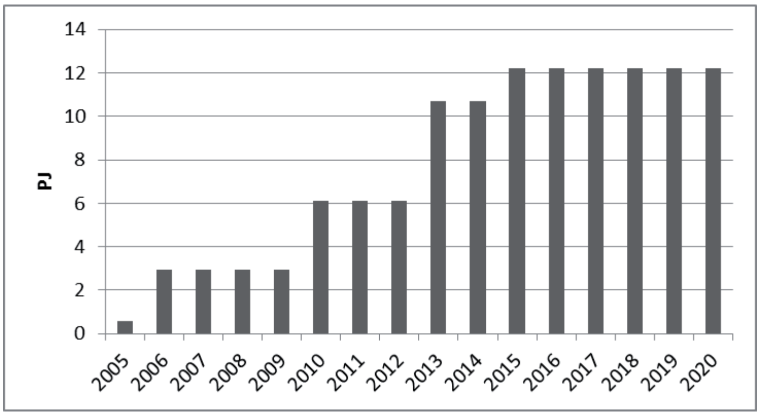

Figure 1. Development in the Danish EEO target. The value for 2005 (0.6 PJ) shows savings from the previous system and is estimated based on reporting from the energy companies. The target is measured in first year savings (Ea Energy Analyses et al. 2012).

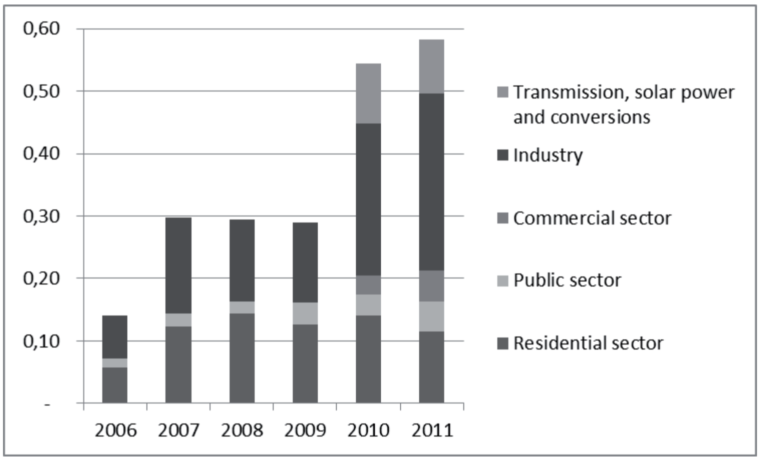

Figure 2. Reported savings in the Danish EEO 2006–2011 distributed on sectors. The reported savings is measured in first year savings. Note that the commercial sector was not reported separately from industry until 2010 and savings in transmission grid, installation of solar power, and switching energy type were not included in the agreement until 2010 (Ea Energy Analyses et al. 2012).

Table 1. The three complementary analyses conducted in the 2012 evaluation to determine the net impact of the savings reported by the obligated parties in 2011.

Analyses	Approach	Purpose	Coverage
Additionality analysis	Interviews with end users	Determine the percentage of additionality.	14% of the obligation in 2010.
Technical analysis	Review of calculations	Determine the percentage of technical accuracy.	20% of the total reported savings for 2011
Statistical case study	Consumption data and reported savings.	Determine whether statistical significant estimates on the effect of energy savings in the EEO can be calculated.	Case study of 331 district heated houses in the municipality of Aarhus.

ish system, the energy companies are only required to document the fact that savings have been correctly calculated and fulfil the requirements. Documentation is only to be provided to the regulator if the project is chosen in the random sampling control. In contrast, in the Italian white certificate system the regulator must approve all projects.

The Danish EEO was evaluated by an independent party in 2008 (Togeby et al. 2012b) and again in 2012 (Ea Energy Analyses et al. 2012). Both evaluations provided input to the negotiations of the terms of the following agreement period, which ultimately resulted in changes in the EEO target and design.

Ea Energy Analyses, in collaboration with NIRAS, and Viegand & Maagøe, carried out the 2012 evaluation of the Danish EEO. The overall purpose of the evaluation was to assess the socioeconomic cost-effectiveness of the EEO framework and, if relevant, to recommended adjustments to the EEO framework and guidelines for the following agreement period starting in January 2013 (Danish Energy Agency 2011). In addition, the evaluation included an assessment of calculation methods, prioritisation factors, documentation, quality assurance, the obligated parties' cost, and the use of external actors.

The political agreement of March 2012 specifies that the effort undertaken by the obligated parties of the EEO as of 2013 should target existing buildings and industry (Danish Energy Agency 2012a). Further, the EEO should emphasise cost-effective savings that would not otherwise have been realised and increase marketization of the savings effort (Danish Energy Agency 2012b). The 2012 evaluation showed that achieving these goals pose several dilemmas for the Danish EEO design and implementation.

This paper focuses on the net savings impact of the savings reported by the obligated parties. The method for determining net impact and evaluation results are discussed, and the subsequent implementation of the recommendations for the new EEO period presented.

Evaluation of net impact

The net impact attributable to a policy instrument used is often a critical issue, when instruments to promote energy savings are evaluated. However, the term net impact is easy to define but generally difficult to measure in an ex-post evaluation (Vine et al. 2012). The net impact is the additional energy saving effect resulting from the obligated parties' efforts. Savings that would be realised without the EEO do not contribute to the net impact. The net impact of obligated parties' effort is generally lower than the reported savings and can be expressed as follows:

Net impact = Reported savings * Technical accuracy in the calculation of savings * Additionality * Rebound * Spill-over.

The *technical accuracy* in the calculation of the reported savings refers to the over (or under) estimation of the savings due to calculation errors or improper/incorrect use of assumptions.

A saving is deemed *additional* if it would not have been implemented or accelerated without the obligated party's involvement. *Additionality* expresses the likelihood that the energy savings would *not* have been realised without the obligated party's involvement.

Spill-over is positive co-benefits of energy efficiency programs and measures to promote energy savings. *Rebound effect* occurs when participants replace the savings achieved with a new or increased consumption of energy. Neither spill-over nor rebound effect were quantified in the 2012 evaluation.

The evaluation included three complementary analyses to assess the net impact of the reported savings in 2011: 1) An analysis of additionality based on interviews, 2) a technical analysis that focused on the calculation of the savings, and 3) a statistical case study that tested whether statistical significant estimates of the net savings impact of the EEO can be calculated (see Table 1).

ADDITIONALITY ANALYSIS

then the instrument is considered cost-effective from a socioeconomic perspective. As the additionality factor has a vast influence on the net impact, it also has substantial effect on the socioeconomic cost-effectiveness. As in the 2008 evaluation of the additionality in the public and business sector, the 2012 evaluation also used interviews to determine the additionality of the reported savings.

There are more than 500 energy distribution companies in Denmark. The evaluation covers 24 energy distribution companies, 697 energy saving projects realised in 2010, and a total of 567 GWh reported savings. The sample of projects for the investigation was a stratified sample of energy companies, focused on major energy distribution companies and large savings projects. The energy distribution companies in the sample represented approximately half of the total obligation of 1.7 TWh in 2010. In 2010, the obligated parties reported 2.0 TWh collectively resulting in a sample size of 28 % of the total reported saving in 2010.

By choosing the major energy distribution companies across the electricity, natural gas, oil, and district heating sectors the sample represented a larger share of the reported savings than would have resulted from a random selection. The choice of sample method stemmed from a desire to cover as much of the savings as possible while the minimising the number of energy distribution companies involved. This, however, means that the evaluation does not cover potential divergent results for smaller energy distribution companies or smaller projects.

209 telephone interviews were conducted with end-users that had received subsidies or advice from an energy distribution company in relation to energy savings project realised in 2010. The interviews represented all energy forms and all end-use sectors, including 46 interviews with end-users from the residential sector.

Several end-users were represented with more than one project in the evaluation sample and the data was therefore screened for unique end-users. Also, the data included a number of faulty contact information as well as a natural lapse as a result of personal renewal, restructuring and lack of time/desire to participate. Lack of contact with an end-user can also be due to poor faulty data, although this has not been confirmed. Aggregated, the interviews cover 30% of the projects represented in the evaluation and 16 % of the total obligation for 2010.Table 2 shows the data collection process.

The questionnaire included a number of questions, to elucidate additionality and net impact:

- To what extent were you, before you were in contact with [the energy distribution company], thinking about realising the energy saving project?
- How likely is it that you, without contact to [the energy distribution company] or [other actors], had implemented the energy within 1 year?
- How likely is it that you, without contact to [the energy distribution company] or [other actors], had implemented the energy within 3 years?
- How critical to the implementation of the project was the subsidy you received?

The questions were only asked when relevant, e.g. only end-users that were reported to have received subsidies were asked about the significance of this. The interview was planned around a specific project and a specific energy distribution company, both of which are mentioned by name. Further, an effort was made to speak with the person within the company or household that was in the best position to answer the questionnaire. The first three questions were identical to the questions posed in the 2008 evaluation; where 100 projects with high savings were surveyed.

There is considerable uncertainty involved, when using interviews to determined additionality. The questionnaire requires the respondents to compare a real and a hypothetical scenario. This can be difficult, even for the honest and supportive respondent (Dyhr-Mikkelsen and Togeby 2011). Similarly, the respondent can deliberately distort the answer. An energy manager might want to take credit for a good project. It can also be difficult for people or companies that have received a large subsidy, to admit that this had no effect on the decision.

Measuring additionality is difficult and challenging (Vine et al. 2010), especially when there are more organisations and programs promoting energy savings at the same time. Using a few questions may be a cost-effective approach, but may be questioned for validity reasons. The four questions above do, however, not stand alone as supplementary questions regarding e.g. project description and reason for renovation were used for cross checking the answers.

Generally, it is estimated that respondents answer consistently and credibly. This is, among other things, based on comparison of answers to other questions in the questionnaire and by comparison with the project title and description. In addition, the results for the public and business sector matched the results from the 100 interviews conducted in the 2008 evaluation. The data set does, however, include errors in the responses, which among other things can be seen in the complimentary qualitative answers. In hindsight, more qualitative questions regarding the additionality would have improved the validity of the interview approach, as would triangulation with more objective methods for determining the baseline such as market data.

The quantitative answers to the question of "the likelihood that the project would have been completed without help" were converted to an additionality factor. For example, a probability of 40 %, thus becomes an additionality of 60 %. Further, the results were weighted by the size of the energy savings of each project.

The results showed an additionality of 46 % at 1 year, and falling to 42 % after 3 years for energy savings project in the public and business sector. Additionality is relatively higher for the biggest energy saving projects, which were reflected in the additionality of industry projects being 52–60 %. In contrast, the additionality of the residential sector was found to be 6–8 %, see Figure 3.

It is estimated that the large number of responses for the public and business sector makes it possible to use the results more generically. Further, the results correspond with the findings of the 2008 evaluation where the additionality for large energy savings projects was found to be around 50 % (Ea Energy Analyses et al. 2008).

The small residential respondent group gives reason to be concerned as to the representativeness of the sample. The small size of the residential respondent group was partially due to

Table 2. Potential and actual interviews conducted with end-users.

	Number of projects	Percentage of projects
Projects in the evaluation sample	697	100%
Contact information available	498	71%
Screening for unique end users	62	9%
Faulty contact information	44	6%
Not reachable	119	17%
Refused interview	61	9%
Completed interviews	209	30%

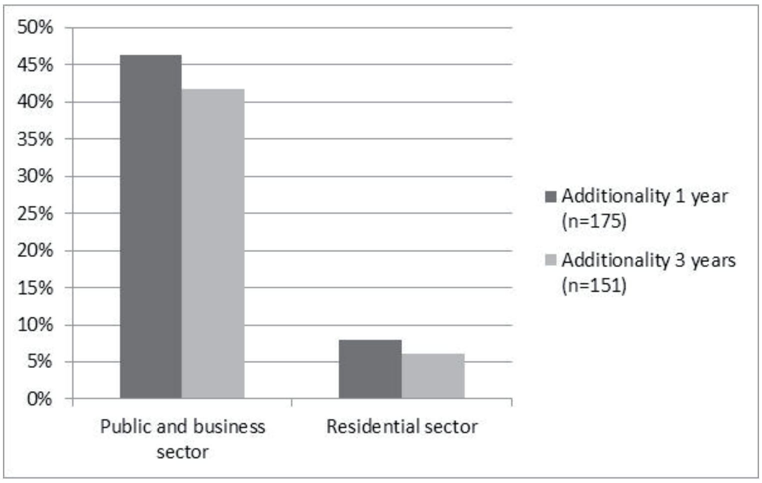

Figure 3. Average additionality for the public and business sector and the residential sector based on interviews with end-users. 46 respondents from the residential sector and 129 respondents from the public and business sector answered the question (Ea Energy Analyses et al. 2012).

the fact that the evaluation in general focused on covering the largest energy saving projects in order to cover as large a part of the reported savings for 2011 as possible. This meant that small end-users were represented in the data collection but did not have first priority.

Also, the questionnaire had a response rate of 49 % and 24 % for large and small end-users, respectively. This is problematic because it can be expected that the end-users who participated in the survey are on average the most positive. The low response rate can be due to the time lapse between the time the respondent received the subsidy or advice and the time of the interview. Maximum time lapse allowed in the selection was a time lapse of 2 years, which may have been too long and might have contributed to the relatively high share of respondents replying "unknown" to the questions. To address this, the evaluation questionnaire would have to be conducted simultaneously with the energy saving effort and not ex-post as currently.

As mentioned earlier, the additionality has a vast influence on the socioeconomic cost-effectiveness of an instrument. An additionality factor below 10 % for the residential sector thus strongly points to low cost-effectiveness. To account for the limited data, and thus the extended uncertainty, the estimate for additionality of energy savings projects in the residential sector was estimated to 20 %. With this correction, a best case scenario is assumed for the subsequent socioeconomic calculations. A larger sample for the residential sector would be preferable, but whereas the results may not be used in generalised ways, it gives, however, the indication that many energy saving projects in the residential sector would have been realised even without the subsidy or advice given by the energy companies.

TECHNICAL ANALYSIS

The technical analysis consisted of a technical review of the documentation delivered by the obligated parties for a selection of specific projects from 2011. It consisted of a review of calculation methods as well as an assessment of assumptions and conditions under which the calculations have been made. The actual energy savings were not ratified by this method; rather, the reported savings were checked against the theoretical assumptions undertaken by independent experts. The review results in a discrepancy factor which together with the additionality factor can be used to calculate the net savings impact.

The analysis indicates a discrepancy of 6 % between the reported savings (kWh) and the estimated savings (kWh) calculated during the technical review. The 6 % discrepancy is measured as the sum of deviation for all the energy savings selected for the review. In general there is a trend that the reported savings are higher than the correctly estimated savings.

The deviations identified during the review can be categorised in two groups:

1. **Calculation errors**: Direct mistakes have been identified in the calculations. This includes for instance incorrect use of conversion factors, and mistakes in relation to quantifying the area of relevance to the energy saving measure or the amount of installations involved in the saving measure.
2. **Improper/incorrect use of assumptions**: Use of assumptions for calculating the savings are incorrect or used in a context which is not relevant. This includes for instance use of a definition of what would be accepted as the reference case (baseline) for measuring the energy saving potential, which in some cases has been assessed as too lax. This type of mistakes are subject to interpretation and one lesson learned in the evaluation is that clearer definitions of the reference case for selected types of initiatives would help clarify the framework within which the energy savings are to be calculated.

In total, 121 reported energy saving projects from 25 obligated parties were reviewed. All projects have been reported for the year 2011. The aim was to include the largest energy saving projects in order to cover as large a part of the reported savings for 2011 as possible. This means that for each sector covered by the EEO, i.e. electricity, heat, oil and gas, the largest energy distribution companies, comprising 50 % of the energy saving target for the sector, were selected for review. In addition, 4 small energy distribution companies were selected. For each energy distribution company the largest energy saving projects were selected, within different categories (covering e.g. the largest of all projects undertaken, the largest projects undertaken specifically within the public, commercial, industry and residential sectors, the largest projects using pre-determined energy saving estimates as well as the largest solar heating projects and efficiency measures undertaken within the distribution grid). As a result 93 of the projects selected for review were measured based on specific calculations and 28 projects were measured using standard values. The selected projects have a reported value of 419 GWh which is equal to approximately 20 % of the total reported savings for 2011.

The technical review of energy saving projects indicates some general trends:

- Most of the mistakes identified appear among the largest projects where specific calculation creates the basis for calculating energy saving potential.
- Some projects do not take the total energy balance into account when calculating the energy saving potential, e.g. ignoring extra energy consumption elsewhere in an industrial process.
- For projects, where the use of a reference case creates the basis for calculating energy savings, the reference is crucial for establishing a valid reference. In some cases, the reference case is too lax resulting in estimates of too high energy savings.

STATISTICAL CASE STUDY

The evaluation includes a case study that tests whether a statistical analysis of the EEO would result in statistically significant estimates of the energy savings impact. Experience shows that the smaller impact to be documented the stronger analysis design is needed. In the case of energy savings, the impact is often small and the size is comparable to random changes in the energy consumption; e.g. changes in how the building is used.

The design focussed on energy savings in a sample consisting of 331 district heated houses in the municipality of Aarhus. 166 of these houses, the *action group*, are applicants who received subsidies under the EEO from the district heat distributor 'Affaldvarme Aarhus' in 2009 for energy saving projects in their houses. The amount of subsidies a single household could receive was based on the expected energy saving, estimated using standard values specified in the EEO. The other 165 houses in the dataset were chosen to make up the *control group*.

All houses in the control group were selected as the neighbour house to a specific house in the action group. No house in the control group had received a subsidy from the local district heat distributor in the observed period (and it was assumed that they had not received help from other obligated parties). The district heating distributor provided consumption data for both the action group and the control group.

Changes in a 12 month energy consumption period before 2009 and a 12 month energy consumption period after 2009 were compared across the control group and action group. All energy consumption data were adjusted by degree days to take into account that some periods are colder than others and more energy will be used for heating during such periods.

The analysis found that the control group experienced a mean reduction in yearly energy consumption of 10.9 kWh/m². This is an unexpectedly high reduction. The action group realised a mean reduction of 24.8 kWh/m², which is 13.9 kWh/m² more than the control group (see Figure 4). Compared to the expected energy savings based on standard values, the exceeding mean energy savings in the action group only accounts for around 44 % of the reported energy savings. The difference is statistically significant. However, the action group realised significantly fewer savings than what was reported.

It is difficult to assess why the expected savings are not realised. The savings are calculated based on standard values defined in the EEO design. End-users fill in a description of the energy saving project on a website. When the project is completed, the end-user reports this to the energy distribution company, which then pays out the subsidy. Part of the overestimation may be due to overoptimistic values of the standard of the existing insulation before the saving project, or overestimation of the window area (the lower the before-standard, the higher the subsidy). Another possibility is that the standard values are not appropriate. This could be the case for a major renovation, which implements a number of cost savings measures as the standard values do not take into account that the combination of several projects can reduce the expected savings.

It is possible that the analysis design did not include all elements relevant to assessing the net impact of the energy saving projects. While the control group is comparable to the action

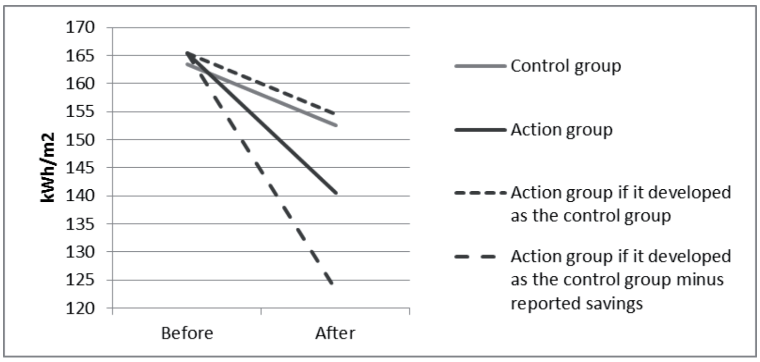

Figure 4. Actual and expected consumption of district heating. The control group experienced a mean reduction in yearly energy consumption of 10.9 kWh/m². The action group realised a mean reduction of 24.8 kWh/m² – 13.9 kWh/m² more than the control group, but 17.4 kWh/m² less than expected (Ea Energy Analyses et al. 2012).

group on all registered characteristic – e.g. comparable mean consumption of district heating in 2008, comparable mean construction year and mean reconstruction year – there is no information on the proportion of the action group, which would have carried out energy saving projects without subsidies from the energy company. If no one would have acted without subsidies, then the result (the 13.9 kWh/m²) could be considered the additional effect. The other extreme is the situation where the subsidy had no influence on the decision to carry out the savings project for any of the households in the action group, and then the additional effect of the energy saving project (the subsidy provided by the energy distributor) would have been zero.

In conclusion the statistical analysis showed 1) an underestimation of baseline when calculating energy savings, 2) the possibility that combining more standard values results in a higher theoretical energy saving potential than can actually be realised, and 3) that a situation where increased comfort as a result of an energy saving measure reduces the effect of the measure. These three points could – separately or in combination – result in substantial overestimation when calculating savings in the residential sector for projects based on subsidy only.

The analysis succeeded in determining a statistically significant estimate on the energy savings impact for the case study. The results do, however, not cover the aspect of additionality fully. As the analysis is based on a case study, the result should be seen as a relevant example – not as a general analysis of all savings in the residential sector.

Evaluation results, recommendations, and application

The evaluation found that the energy distribution companies meet the overall saving obligation. In 2011, 2,098 GWh savings were reported, which is more than the obligation. The net impact of the effort was, however, according to the evaluation results significantly lower, namely about 760 GWh (36 %) when taking into account the technical discrepancy factor and especially the additionality factor. The significant difference between reported savings and net impact has major influence on the socioeconomic cost-effectiveness of the EEO.

Following the evaluation negotiation for a revised EEO design took place and the energy distribution companies chose to sign a new EEO agreement with the Minister of Climate, Energy, and Building in November 2012. The oil distributions companies also decided to sign the agreement.

SAVINGS IN THE INDUSTRY SECTOR

The 2012 evaluation found that the net effect of the reported savings in the public and business sectors was 45 %. This is significantly higher than what was achieved in the residential sector. The majority of the savings are realised in large projects within the industry sector.

In the Danish EEO, savings in industry are considered attractive to the obligated parties as they often provide significant savings within a single project and thus reduce administration costs. Furthermore, the 2012 evaluation shows that energy savings in industry under the EEO are profitable for the companies and have a high net impact (Ea Energy Analyses et al. 2012). The experience from the 2012 evaluation is that when left to the discretion of the obligated parties the most cost-effective and dominating sector to realise savings in is industry. Most often the savings are realised by providing subsidies that reduce the payback time and the need for risk coverage of the investment, and end-users can use the subsidies to buy the advice of professional consultants.

Many of the energy savings projects in industry have a very attractive business case, with payback times as short as 1–2 years. A sample of 56 projects (where information on payback time was available) shows that 20 % of the projects (equivalent to 26 % of the energy savings) have a payback period less than 1 year before potential subsidies. In a few cases the subsidy has even exceeded the investment (Bundgaard 2012). While not actually against the rules in the Danish EEO design, it is difficult to argue that subsidies exceeding the investment are appropriate.

With regard to very large projects and thus very large subsidies, there may be a special reason to keep an eye on the additionality factor. A strategic response from respondents, to which the subsidy represents a very high proportion of the investment, must be expected. The Danish EEO takes the additionality issue into account by requiring that the obligated party – or a third party – must be involved in the energy savings project before it is initiated. Recent studies show, however, that the current requirement might not be enough to ensure early involvement and consequently an acceptable contributing factor (Bundgaard 2012; Ea Energy Analyses et al. 2012). For very large projects (e.g. greater than 50 GWh) it can be argued that if documentation of evidence of early involvement were required and monitored as part of the random sampling, it would improve the net impact of the EEO.

Limitations in relation to both payback time and the subsidies' proportion of investment for energy savings programmes are not without precedence in Denmark (Competition and consumer protection agency 2002; Ministry of Finance 2002). While it can be argued that introducing similar requirements would require too much administration and potentially result in significantly fewer energy savings realised, this also represents two dilemmas: Is it appropriate to support highly profitable projects because of the risk that energy savings will not be achieved if companies do not receive subsidies? And can the administrative burden in relation to the evidence of payback time legitimise subsidies, exceeding the investment costs? The 2012 evaluation recommended not giving subsidies to energy saving projects with a simple payback time is less than 1 year (primarily relevant for industry) and in addition, requiring that the subsidies cannot exceed 30 % of the investment.

Of these recommendations, the following were implemented:

- Limitation on payback time was applied as suggested. However, limitation in the form of subsidy limits as % of investment was not applied.
- Further, a requirement for documentation and calculation of simple pay-back time for projects using specific calculation method was introduced.

SAVINGS IN THE RESIDENTIAL SECTOR

About 30% of all energy consumed in Denmark is used for heating, ventilation, and lighting in buildings, and the potential savings in this category are quite substantial. In order to realise the government's long-term goal: that the entire energy supply – electricity, heating, process, and transport – is covered by renewable energy by 2050, a substantial part of these potential savings must be realised.

As opposed to the EEO in e.g. the UK, the Danish EEO does not have a strong focus on fuel poverty nor the residential sector. On the contrary, the Danish EEO has had a strong interest in realising the set target at minimum costs, regardless of sector and energy form. However, it is generally recognised that it is a challenge to find economic ways to reduce energy consumption in existing buildings. This has been and will continue to be a dilemma for the Danish EEO design and implementation.

The 2012 evaluation showed that only 20 % of the savings in residential sector could be contributed to the measures used in the EEO. This is especially true of apartment buildings, where the average additionality is below 10 %. For single family houses the figure is a little better, at 30–35 % (Ea Energy Analyses et al. 2012). Thus, the subsidies or advice provided through the EEO are negligible for realising the savings compared to other determining features.

One explanation for this is that energy renovations of existing buildings are costly, both from a user perspective and a socioeconomic perspective. The challenge is that it is expensive to improve energy efficiency in an existing, medium efficient building which means that the investment cost alone will be high (Kjærbye 2008; Kragh and Wittchen 2010); each building has a limited energy consumption, which means that the instrument costs of for example obligatory energy audits at the time of sale/purchase quickly becomes too high. Denmark also already has a very high level of taxation on energy used for heating in buildings. On top of the basic energy tax fall separate taxes for CO_2, NO_x, and SO_2, plus a public service obligation (PSO) payment for electricity. In total, the taxes typically exceed 100 % of the energy price before tax. This gives a strong economic incentive to realise energy savings in residential sector even without the EEO, and thus making the savings not already realised less attractive from an economic perspective (Togeby et al. 2012a).

The experience from the Danish EEO is that an EEO may not be the best instrument to realise the energy savings potential in existing buildings. If the renovation is already decided, one may argue that it implicitly is difficult to achieve a high contribution factor. However, the dilemma is that the energy saving potential in existing buildings cannot be ignored if the climate change and energy security objectives are to be achieved. Thus it is important to supplement the EEO with other instruments.

Promoting energy efficiency in the residential sector is difficult, especially if program administrators assume a simple rational actor model on how people think and behave: e.g., just provide information and subsidies, and people will renovate their house and buy energy efficient equipment. Lutzenhiser et al. (2009) and Sullivan (2009) studied alternative models that describe the different challenges and constraints facing consumers when using energy and deciding on energy efficiency investments, and find that – unfortunately – it is not that simple.

One of the main challenges is the timing of the policy instruments. The cost of energy saving is much lower, if implemented, when the buildings are to be renovated anyway. If it is possible to influence the owner at the exact time when they plan to renovate their houses, this can improve the economics significantly because the marginal cost of improving efficiency is much lower than the total cost of the renovation (Kragh and Wittchen 2010). The question is then how to design measures advocating *energy efficient renovation* rather than *energy renovation*?

The 2012 evaluation recommended that the revised EEO design should address how to handle heat savings in the residential sector in the future. One recommendation was to focus the effort on market transformation, i.e. the entire value chain from the manufacturer, supplier, and installer to the end-user (IEA 2010; IEA 2011; Wymelenberg 2013). One way to achieve this could be to work with installers and suppliers in the building sector. This is the goal of the Danish Knowledge Centre for Energy Savings in Buildings, which recently received a positive evaluation. (Togeby et al. 2012a). Further, the EEO subsidies should be coordinated with the new system of subsidies for energy renovation carried out in 2013 and 2014, e.g. prioritise subsidies for energy consultancy, procurement, and other activities in the residential sector during this period.

Of the evaluation recommendations, the following were implemented:

- The recommendation of focus on market transformation for savings in the residential sector was not applied. However, in the new period specific market impact with verifiable effect may be counted towards the target.
- Existing buildings and thus the residential sector are prioritised in accordance with the political agreement. The subsidy scheme for energy renovation has been cancelled. Another subsidy scheme for renewable energy to process purposes has been initiated, wherein energy inspection is a prerequisite for subsidies and subsidies are not allowed for heat pumps, thus coordinating with the EEO.

Further, to address the challenge of finding economic ways to reduce energy consumption in existing buildings the Danish government will in 2024 publish a strategy for how to renovate existing buildings (Political agreement 2012). The strategy will include all building types, including public housing and private rental buildings. Also the measures in the EU Energy Efficiency Directive covering energy saving in public buildings – that 3 % of total floor area owned and occupied by central government bodies should be renovated every year to meet minimum energy performance requirements – will address the challenge of realising energy savings in existing buildings.

MONITORING AND VERIFICATION

The technical analysis found a discrepancy of 6 % between the savings (kWh) reported by the energy utilities and the estimated savings (kWh) measured in the sample chosen for quality control the evaluation. The statistical case study suggests that only 44 % of the reported energy savings in the residential sector are in fact realised. Both results emphasize the importance of monitoring, verification, and possible sanctions.

Based on these two analyses the evaluation recommended that the quality of documentation and savings calculations be increased by improving guidance materials and e.g. publishing a case catalogue where documentation and calculations are illustrated, and that the number of samples in the annually random control sample be increased. Further it was recommended to introduce different types of calculation methods for specific calculations – covering definition of new installations (industrial productions and buildings), situations where the production capacity is increased, as well as situations where production facilities are closed or integrated into other production facilities. Lastly, the technical and statistical analysis led to the recommendation that sanctions for non-compliance to the rules should be introduced. This could e.g. include publishing the results of the annually random control sample and/or introducing extra monitoring for companies that display non-compliance.

Of these recommendations, the following were implemented:

- Adjustments of calculation guidelines in regards to obvious savings, pre-subsidies, and natural replacement e.g. introducing a minimum baseline for insulation projects of 100 mm.
- The establishment of a verification unit that is charged with pre-approving documentation and calculation as well as providing guidance in specific and general issues.
- Specification of the difference between "technically obsolete" and "non-technically obsolete" for district heating grids.
- Monitoring and verification has been granted extra resources, and it is expected that this will result in and increased monitoring effort.

Conclusions

The 2012 evaluation of the Danish EEO found that the energy distribution companies meet the overall saving obligation. In 2011, 2,098 GWh savings were reported, which is more than the obligation. The net impact of the effort is however, estimated to be about 760 GWh (36 %).

The difference is due to several factors: The technical review of the calculation methods and assumptions found a discrepancy of 6 % between the savings (kWh) reported by the energy utilities and the estimated savings (kWh) measured. Further, a statistical case study of district heating savings in the residential sector, showed high overestimation of savings most probably affiliated with poor baseline measures. This led to the introduction of new types of calculation methods for specific calculations, that the minimum baseline insulation was changed from 0 to 100 mm and specification on extended documentation requirements of the payback-time if projects are receiving subsidies in the EEO design for the new agreement period.

Based on an interview approach the additionality was found to be particularly low in the residential sector' energy savings (20 %) as opposed to energy savings realised in the public and business sector (45 %). The low additionality can *inter alia* be contributed to the fact that strong incentives to realise energy savings in residential sector even without the EEO is present and thus making the savings not already realised less attractive from an economic perspective. The evaluation recommended that the new EEO design would address the additionality issues in order to accommodate more economically profitable savings in the residential sector.

There are substantial opportunities to improve energy savings in the industrial sector (IEA 2011). Realising these savings can represent a challenge for policy makers e.g. because of widespread hesitation towards using taxes or CO_2 quotas to motivate industry to higher energy efficiency for fear of hampering the competitiveness of the industry. The 2012 evaluation suggests that EEO or similar measures may be a relevant instrument in such cases. The evaluation found that energy savings in the public and business sector are generally profitable for the companies while still having a high net impact. Some subsidies given under the EEO are, however, inappropriately high and the evaluation recommended implementing a limit of payback-time to 1 year for projects receiving subsidies. This was included in the new EEO design.

As the case was with the 2008 evaluation of the Danish EEO, it is the opinion of the authors of this article, that the 2012 evaluation overall have had a pronounced effect on the design of the Danish EEO for the next period. The EEO agreement between the obligated parties and the Danish Minister of Climate, Energy, and Building covers the period 2013–2020, and the first phase of this will be evaluated early 2015.

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