Evaluation of free-of-charge energy audits

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Abstract

The Danish government is currently reviewing the publicly funded energy efficiency activities in Denmark, and evaluations are being carried out to provide the necessary basis for decision-making. One of the largest activities is the free-of-charge energy audit[1] provided to all enterprises with an electricity consumption above 20 MWh/year by the electricity network companies[2]. An evaluation of this activity was carried out in 2004. It was the first full scale evaluation of the activity.

Free-of-charge energy audit program has existed since the early 1990's and approximately 13 million EUR is being spent annually on this activity. Apart from the energy audit itself, the program also aims at promoting other energy efficiency activities including various campaigns and more permanent offers such as the A-club and voluntary agreements.

The primary aim of the evaluation was to establish the achieved net electricity savings as well as the customer satisfaction and review the present organisational and monitoring set-up.

The evaluation employed three approaches:

1. A review of existing material and databases and a survey among auditors (background).
2. Graphic and econometric net-impact analyses based on statistical information on the electricity consumption of participants and non-participants (macro-level).
3. Ten case studies of different types of enterprises (micro-level).

The paper will present the evaluation methodology and discuss the strengths and weaknesses of these in addition to a presentation of some of the evaluation results.

Introduction and background

The Danish government is currently reviewing the publicly funded energy efficiency activities in Denmark, and evaluations have been carried out to provide the necessary basis for decision-making.

One of the largest activities is the free-of-charge energy audit provided to all enterprises with an electricity consumption above 20 MWh/year by the electricity network companies. Free-of-charge energy audits have existed since the early 1990's.

The annual budget for the program is at present about 13 million Euro (i.e. about 100 million DKK). This figure does not include the cost, which the customers themselves incur due to time spent in relation to the audit and investments made in energy efficiency improvements. The budget costs are recovered through the electricity tariff.

Apart from the energy audit itself, the program also aims at promoting other energy efficiency activities including var-

1. Not to be confused with the Energy Management Scheme (ELO)
2. In Danish: Elnetselskabernes vederlagsfrie erhvervsrådgivning.

ious campaigns and more permanent offers such as the A-Club and voluntary agreements.

The present paper intends to present the first full scale evaluation of the Danish free-of-charge energy audit program. The focus is a discussion of the evaluation approach and its strengths and weaknesses but some of the results of the evaluation are also included.

THE FREE-OF-CHARGE ENERGY AUDITS

The free-of-charge energy audit program is based on the understanding (i.e. problem theory[3]) that a large potential for energy savings in enterprises is not realised and that one of the main barriers at enterprise level is lack of knowledge about available saving options, cost-effectiveness, and how best to start implementing savings measures.

An energy audit can provide enterprises with the required information about cost-effectiveness and "how-to". The program theory[4] is that this information in many cases will be sufficient to help the enterprises from *thinking* about energy efficiency to *acting*. Also, it is assumed that the audit must be *free-of-charge* in order to generate sufficient interest (see also further ahead on the results of the micro-level evaluation). One of the modifications that have been made to the program over the years is that the enterprises may choose between two types of audit; namely a *complete audit* or a *partial audit* of the enterprise. The partial audit focuses on specific installations or systems that the enterprise has expressed an interest in.

Should an enterprise decide to implement some of the identified energy savings measures, a more detailed audit can be carried out, however, not free-of-charge.

The program targets all electricity end-uses and to some extent also other energy and water end-uses. The network companies are however, only required to track the electricity savings and are only credited for the electricity savings (i.e. network cost-effectiveness is judged on electricity savings only).

No definite targets were originally defined for this program. However, the Danish Energy Authority demanded in October 2002 that each year about 10% of all larger enterprises, or about 10% of their total electricity consumption, are offered an energy audit. Assuming that 20% of the 10% do not wish to accept the offer, all enterprises should be reached within an 8 years cycle. Analysis of penetration, cost-effectiveness and avoided CO_2 emissions is thus carried out regularly as part of the overall DSM planning regime and reported to the Danish Energy Authority. It is worth noting that while the audits are registered in a common database (UNITOOL), this database has not been used for government monitoring of electricity network company compliance.

There are about 200 energy auditors and they are equipped with various tools (models, guidebooks) that help make the audit offer relatively uniform across the country. The auditors are paid by the electricity companies.

Evaluation approach

The most recent evaluation of the free-of-charge energy audit program was carried out in 2004. It was the first full scale evaluation of the activity. It was also the first evaluation task that was formulated using the terminology and method developed in the Danish evaluation guidebook[5] completed the previous year.

The evaluation was requested and financed by the Danish Energy Authority. The evaluator was a consortium consisting of the Institute of Local Government Studies (AKF) and SRC International (SRCI, a private consulting company).

The evaluation results were to be used in an overall assessment of the existing mix of energy efficiency programs targeting the Danish consumers. Furthermore, the evaluation was to be used to point to improvement possibilities in the contents, target group, and organisational set-up of the free-of-charge audit program.

The primary aim of the evaluation was to investigate the *net-impact* of the program. Since a large number of energy efficiency promotion activities have been targeted at businesses over the years (and still are), one of the challenges was to establish how much of the change in energy efficiency can be attributed to the free audit program. It is also generally believed that the audit program sensitises businesses to other activities such as the campaign for energy efficient ventilation. The extent of this was also to be established.

Furthermore, the evaluation was to assess the cost-effectiveness of the program from various perspectives, assess the customer satisfaction, and review the present organisational and monitoring set-up.

The evaluation team chose to employ three approaches (see *Exhibit 1*):

1. Background evaluation – A review of existing written material, in particular the planning and documentation reports produced bi-annually by the electricity network companies since these form the basis for government control of the program; Analysis of the contents of the UNITOOL database; and a small survey among the auditors;
2. Macro-level evaluation – Statistical assessment of the impact that can be generalised to national level – ambitious, given the timeframe, but necessary in order to establish the contra factual events (what would have happened in case of no audit, something that the case-studies cannot answer);
3. Micro-level evaluation – Assessment of impact, cost-effectiveness, and customer satisfaction among success stories (best cases) using a case study approach.

Employing three approaches allowed the evaluation team to cross check certain information and thus to increase the credibility of the evaluation results.

In the following the three approaches are outlined and some of the main findings and lessons learned presented.

3. Realistic evaluation, R. Pawson & N. Tilley, Sage Publications, 1997, ISBN: 0761950095.
4. Realistic evaluation, R. Pawson & N. Tilley, Sage Publications, 1997, ISBN: 0761950095.
5. Handbook in evaluation of energy savings activities, Danish Energy Authority, 2003.

Exhibit 1. *Three approaches were employed in the evaluation to answer the questions of the evaluation.*

Background evaluation	Marco-level evaluation	Micro-level evaluation
- Do planning and documentation reports comply with the law? - Historical development - Audit concepts - Context - Survey of auditors for suggestions for improvement - Impact according to UNITOOL & documents	- Net-impact according to national electricity consumption data - Factors that further or hinder impact	- Impact - Customer satisfaction - Economic aspects - Link to commercial efficiency services - Factors that further or hinder impact - Suggestions for improvement - Side effects

Exhibit 2. *Development in audit activity and impact according to the DSM documentation and plans.*

	2000	2001	2002	2003	2004
Documentation (actual)					
1st year electricity saving (GWh)	109	86	111	-	-
Electricity network company cost (million EUR)	7.1	7.8	9.8	-	-
Audit price (EURcent/kWh saved 1st year)	7	9	9	-	-
Plans (budget)					
1st year electricity saving (GWh)	-	-	110	109	94
Electricity network company cost (million EUR)	-	-	12.8	12.8	11.4
Audit price (EURcent/kWh saved 1st year)	-	-	12	12	12

Exhibit 3. *CO_2 shadow price by customer segment according to the DSM documentation and plans.*

Segment	Size	Realised 2002 (EUR/ton)	Planned 2003 (EUR/ton)	Planned 2004 (EUR/ton)
Industry	20-100 MWh/year	18.0		20.3
	100-500 MWh/year	5.8		7.5
	>500 MWh/year	-8.1	-2.4	-4.7
Total industry		**-6.2**		**-2.2**
Trade and service	20-100 MWh/year	74.0		26.5
	100-500 MWh/year	43.4		18.5
	>500 MWh/year	18.4		15.2
Total trade and service		**38.7**		**19.3**
Public	20-100 MWh/year	105.1		34.0
	100-500 MWh/year	28.6		27.8
	>500 MWh/year	19.1		27.4
Total public		**31.2**		**28.6**
Agriculture	20-100 MWh/year	129.3	41.4	28.2
	>100 MWh/year	24.9		17.2
Total agriculture		**34.8**		**22.0**

Please, note that not all the results of the evaluation are shown in this paper – only illustrative excerpts. Interested readers may consult the four evaluation reports.

Background evaluation

An overview of the objectives of the background evaluation is presented in *Exhibit 1*.

Law no. 350 and annual task letters define the framework for the audit activity. The progress and impact are monitored by the Danish Energy Authority through the bi-annual DSM-planning and DSM-documentation reports. The responsibility for the audit program rests with the individual electricity network company but their umbrella organisation, ELFOR, coordinates certain elements such as the reporting to the Danish Energy Authority. In addition to the required reporting procedure, ELFOR has taken the initiative to develop a common database for the audit activity, namely UNITOOL. Furthermore, a lot of the electricity network companies have their own individual databases. A very impressive amount of information thus exists on this activity.

REVIEW OF WRITTEN MATERIAL

Very briefly it can be said that great effort has been made to document the activity but – as is most often the case – the need for information develops as experience is gathered. Therefore comparison of figures from year to year was not always possible (see *Exhibit 2*). Also the associated bureaucratic burden has to be considered.

The details of the review of the planning and documentation reports, law texts, earlier evaluation reports, etc. are not presented here since they have limited relevance to an international audience.

The result of the total audit activity in 2002 is according to the DSM documentation approximately 122 GWh implemented first year savings. According to the most recent DSM plan the electricity network companies expect to achieve 203 GWh implemented first year savings in the period 2003-2004 (see Exhibit 2). The electricity network company cost to achieve this impact was 9 Eurocent/kWh in 2002 and 12 Eurocent/kWh in 2003-2004[6]. The increase in relative cost should not be regarded as indicative of a lower impact per Euro, since actual expenditures tend to be lower than the budget historically.

The CO_2 shadow price of the planned activity is expected to be between minus 2.4 Euro/ton CO_2 for industry larger than 500 MWh/year and 41.4 Euro/ton CO_2 for agriculture below 100 MWh/year (see *Exhibit 3*). Exhibit 3 clearly shows the dilemma between optimal cost-effectiveness and the obligation to address all customer segments.

The district heating and natural gas sectors have recently become obliged to offer the same energy efficiency services to their customers, as do the electricity network companies and to document the activities. The main issue appears to be how exactly to integrate the work and documentation optimally. The three sectors have already on their own accord started the process in that they cooperate in energy advice centres that handle most of the audits.

SURVEY AMONG AUDITORS

A survey among the auditors was added to the evaluation to provide an up-to-date impression of the audit program situation. A small questionnaire with 8 open questions was sent to 28 auditors of which 21 replied.

The primary concern of the interviewed auditors is the lack of liberty to contact the customers of their choice while being measured on cost-effectiveness. Therefore it is not possible to focus solely on the most attractive possibilities for savings. This should be justly accounted for in the cost-effectiveness measurement. This concern should be seen in the light of competition. So far the right to collect the necessary financing and to carry out the free audits has been the prerogative of the electricity network companies. However, ordinary consultants have been eager to access this market and they argue that the task should be open to bidding. The network companies argue that this could result in cream skimming and jeopardize the vital long-term bond with the customers.

As a result of the introduction of a free energy market in Europe and the resulting restructuring of businesses, there is quite understandably a need for a review, clarification of roles and simplification of the framework within the energy efficiency field in general including the free audit program.

IMPACT ACCORDING TO UNITOOL

UNITOOL contains first of all data on the audited customers' electricity consumption before the audit, branch affiliation (public branch codes), recommended electricity saving measures (kWh savings and investment costs), and implemented measures (estimated kWh savings and investment costs) by type of end-use. It does not contain information on enterprise size measured in number of employees. The identification of customers is by name and address only and not by a public identification number or a customer number that would allow quick integration of data with public databases or customer billing databases. This is mainly due to the fact that the database was not originally developed with large-scale evaluation in mind.

The UNITOOL database proved to be far less complete than expected and a significant amount of time was spent trying to improve the situation with limited success. This meant that an impact analysis based upon UNITOOL alone could result in a distorted picture[7]. Still, the exercise was carried out as planned.

Although it is time consuming for the individual auditor to report every audit to a common database that may not be of the same format as their own, it is very useful seen from a societal perspective especially if integrated with the obligatory documentation reports to the Danish Energy Authority. The umbrella organisation ELFOR has therefore as a result of the evaluation committed themselves to validating the data and making sure that all audits are included in the near future.

Very briefly the figures in UNITOOL seemed to indicate the following:

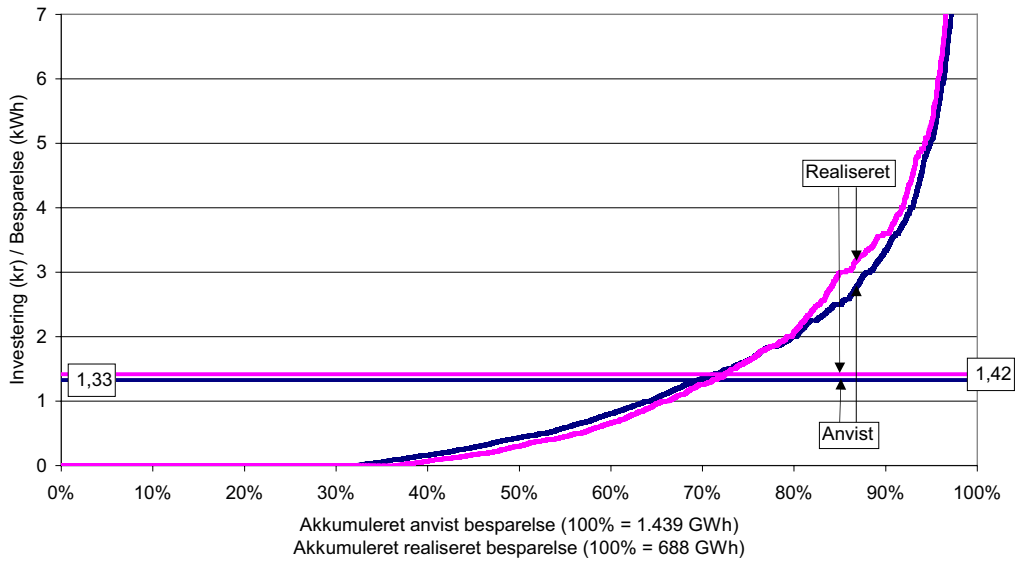
- The number of audits carried out within the period 1987-2003 and registered in UNITOOL is ca. 14 500 enterprises. There were about 115 000 enterprises in Denmark in 2002.
- Audits have been carried out in all branches but in particular in the food industry and chemical industry (12% each) and least in agriculture and construction industry. (0.5% and 0.4%).
- About 48% of the identified kWh savings potential has been realised. The distribution between end-uses is very even.
- Simple payback time of the implemented measures is in average 3.6 years.
- The customer investment is 19 Eurocent/kWh for the implemented measures (see Exhibit 4).

An example of the cross referencing that was made possible by using more than one evaluation approach is the importance of the payback time and the size of the required investment for the implementation of measures. Exhibit 4 shows the data registered in UNITOOL at the time of the evaluation.

According to UNITOOL the payback time for the investment does not appear to be of importance or not for whether the enterprises will implement a recommended measure, since the curve for the implemented savings is almost equal to the curve for recommended measures. The average enterprise investment is a little higher for the implemented measures than the recommended measures, which indicates that the enterprises not only implement the cheapest meas-

6. 1 Euro = 7.44 DKK.
7. This also had an impact on the statistical evaluation.

Exhibit 4. *Investment per kWh saved according to UNITOOL data. X-axis – Accumulated electricity savings; Y-axis – Investment in DKK / electricity savings in kWh; Anvist – recommended; Realiseret – implemented.*



ures – especially since 32% of the recommended advices do not require any investment at all.

The case study on the other hand (see further ahead) indicates that the payback time *is* of importance. The reason for this difference is not clear.

Both investigations though agree that the size of the necessary investment is irrelevant for the implementation. This seems in coherence with the fact that partial audits by definition focus on the areas that have the interest of the client. If an enterprise is about to replace their motors then it will be natural to focus on implementing the measures relating to increasing the motor efficiency, in spite of a higher investment, rather than for example teaching the employees to switch off the light when they leave the room.

Macro-level evaluation

As mentioned earlier the purpose of the macro-level evaluation was to establish the net-impact of the audit program and identify factors that further or hinder impact. A combination of graphic analyses and econometric analysis was applied, the graphic analyses also being used by the evaluator to get a feeling of the data before starting the multiple regression analysis.

The main limitation of the graphical analyses was that it was assumed that there is a correlation between the number of employees and the electricity consumption of a given enterprise. This assumption was later tested in the econometric analysis.

The savings reported in the DSM documentation and in UNITOOL are to a large extent based on the preliminary estimates made by the auditors at the time of the audit. It is only on very rare occasion possible to verify the actual savings, since individual metering on the concerned equipment is rare. An investigation of the development in the electricity consumption data for audited and non-audited enterprises using accounting databases could overcome this uncertainty.

SAMPLE CONSTRUCTION AND DATA COLLECTION

The intention was to create a sample consisting of all enterprises, which received an audit, and a comparison group of enterprises that did not receive an audit. The enterprises in the comparison group were selected at random within the different branches and sizes (stratified random selection). In populations (i.e. strata) with only a small number of enterprises the number of enterprises in the comparison group was increased by a factor 1.5-2.5 in order to increase the statistical certainty.

The original idea was that the treatment group would contain about 10 000 enterprises. However, various problems resulted in a sample size of approximately 1 400 enterprises in the treatment group and approximately 6 100 enterprises in the comparison group. Not all of these data were used in each of the analyses.

The necessary dataset was combined from the following databases:

- Data from UNITOOL on which enterprises have received an audit;
- Data from selected electricity network companies (12 largest) on the electricity consumption 1992-2002 for enterprises that have received an audit and a comparison group which has not received an audit;
- Data from the Danish Energy Authority on which enterprises have received grants and which enterprises have entered a voluntary agreement;
- Data on electricity prices from the Association of Danish Energy Producers;

Exhibit 5. *Distribution of annual percentage changes in electricity consumption in the treatment group (light grey) and the comparison group (dark grey) for the small sample (1992-2001).*

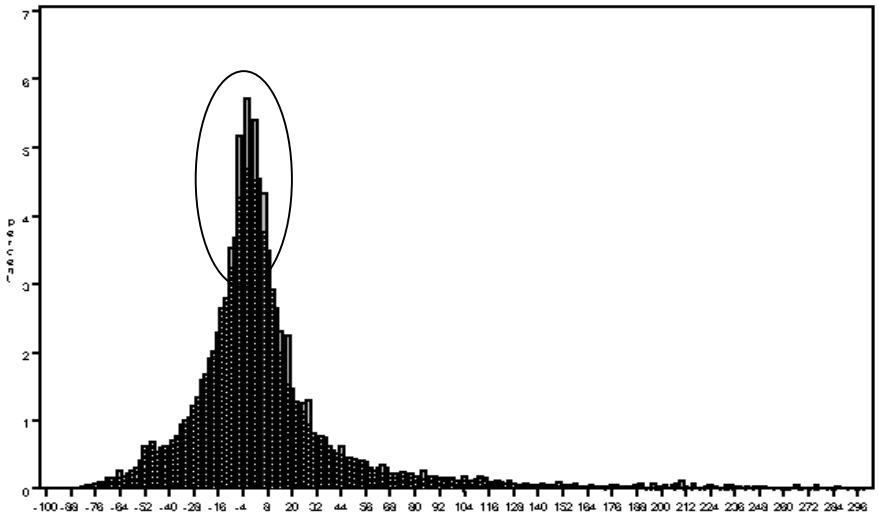
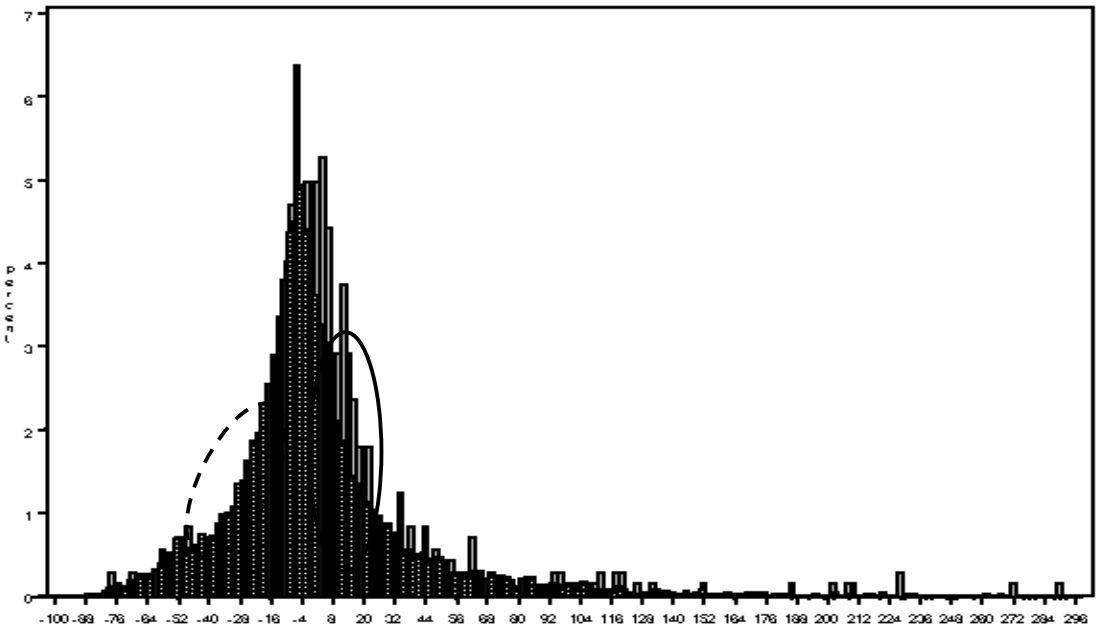


Exhibit 6. *Distribution of annual percentage changes in electricity consumption in the treatment group (light grey) and the comparison group (dark grey) for the larger sample (1998-2001).*



- Data from the national registration of enterprises on the production site number of the enterprises;
- Data from Denmark's Statistical Office on the employment in the enterprises.

Combining these databases was not simple. For example, the enterprise entity can be defined in several ways such as production site or a business entity consisting of several production sites. Also one production site may have several meters registered independently of each other, just to name a few. Energy sector restructuring and changes in accounting systems proved to cause great difficulty in retrieving older data and creating time series.

Furthermore, the time available to the electricity network companies for retrieving the requested data was very limited.

GRAPHIC EXERCISE 1 – AUDITED ENTERPRISES COMPARED TO NON-AUDITED ENTERPRISES

Graphic exercise 1 investigated the development in the electricity consumption in the group of audited enterprises compared to the comparison group.

The hypothesis was that the consumption would be lower or at least stagnant in the audited group compared to the control group.

The limitation of the exercise was that the importance of type of branch and level of energy consumption was not in-

vestigated, since available time and sample size did not allow for this to take place.

The initial analysis consisted of plotting the average electricity consumption per employee for the treatment group and the control group. Due to difficulties in obtaining sufficient non-faulty data, analyses were made for both a long time frame (1992-2001, small sample) and a short time frame (1998-2001, larger sample). Thus, only enterprises for which consumption figures were available for all years were included. Both graphs showed that the average electricity consumption per employee was significantly higher all years for the audited enterprises. This seems to indicate that the audit activity has been focused on the electricity intensive enterprises, just as requested by the government and economic sense. The graphs also show that the average consumption per employee in the small sample is 16-27 MWh/employee in the comparison group and 27-56 MWh/employee in the treatment group, while it in the larger sample is 150-200 MWh/employee in the comparison group and 430-1 150 MWh/employee in the treatment group. The larger sample (1998-2001) thus seems to include more energy intensive enterprises in both the treatment and the comparison group.

Then the change in electricity consumption from one year to the next was investigated for both time periods and two histograms were produced (see *Exhibit 5 and 6*). In both cases, the difference between treatment and control group is not significant. In the small sample (year 1992-2001), the treatment group can at best be said to be a little more stagnant in the consumption level than the comparison group (i.e. the light grey columns reach up higher around 0% than the dark columns). In the larger sample (year 1998-2001), the treatment group seems at best to have a higher or stagnant consumption level than the comparison group (i.e. the light grey columns reach up higher around 0-20% than the dark columns).

Finally, the development in the electricity consumption around the year of the audit was investigated, namely two years before and two years after the year of the audit, for both the treatment group and the comparison group. Three methods were used:

1. Graphic representation of the average consumption per employee (i.e. total consumption within the group divided by the total number of employees in a given year).
2. Graphic representation of the change in average annual consumption per employee relative to the year of the audit.
3. Graphic representation of the average change in annual consumption per employee relative to the year of the audit. This is included in order to counteract the fact that in the two methods above changes in consumption for large businesses is given more weight than that of a small enterprise.

The data represented the period 1993-1999 and 21 graphs were made. Sometimes the consumption increases and sometimes it decreases after the audit year. The graphs only seem to show that both the treatment group and the comparison group follow the same general trend over time.

GRAPHIC EXERCISE 2 – SIZE OF ELECTRICITY CONSUMPTION

The graphic exercise 2 investigated the importance of consumption level in the response to the audit.

According to the hypothesis the audit should influence the consumption in large or energy intensive enterprises differently than in less energy consuming enterprises. In other words, larger levels of consumption result in a larger interest in savings and therefore a greater fall in consumption after the audit. The counter argument is that large consumption levels might mean that the enterprises had already implemented energy efficiency measures on their own initiative and therefore there should not be a difference as to scale.

Limitations to test the hypothesis are the lack of a comparison group; therefore the "natural" development could not be distinguished. Furthermore, the variation in energy consumption by branch type is not accounted for. Also, if the hypothesis is proven as correct, then the cause of the lower consumption could be the impact of other energy efficiency programs, and not the free energy audit.

The sample consisted of all audited enterprises split into four groups according to annual consumption level (below 100 MWh/year, 100-200 MWh/year, 100-500 MWh/year, above 500 MWh/year).

The methods of analysis were method no. 2 and 3 explained in the graphic exercise 1 above. Neither of the two graphs confirms the hypothesis. Enterprises within the interval 100-200 MWh/year appear to have reduced their consumption level but the smaller consumer group and the two larger groups show an increase or only a very temporary decrease in consumption.

GRAPHIC EXERCISE 3 – AUDIT INTENSITY

With graphic exercise 3 the importance of the audit intensity on the response to the audit was investigated. Audit intensity was defined as:

> a) The amount of electricity consumption by equipment audited relative to the total consumption, measured in kWh/year (below 35% of total electricity consumption, 35-70% of total electricity consumption, above 70% of total electricity consumption) and as
>
> b) The identified electricity savings potential relative to the total annual electricity consumption of a given enterprise (recommended savings below 12.5% of total electricity consumption, 12.525%, above 25%).

The hypothesis was that the greater the share of the energy consuming equipment investigated, or the greater the identified saving potential, the greater realised savings will be.

The limitations of the exercise were the same as for graphic exercise 2.

The sample consisted of all audited enterprises split into four groups according to annual consumption level and three groups according to audit intensity applying two different definitions of intensity.

The methods of analysis were method no. 2 and 3 explained in the graphic exercise 1 above.

The graphical analysis of audit intensity type "a" did not show a relation between the consumption share of equip-

ment audited and the absolute or relative amount of electricity saved. The graphical analysis of audit intensity type "b" showed that the larger the identified savings potential, the greater the realised savings (method 3) and that the reduction in consumption appears to start the year before the audit takes place. The "premature" reduction in electricity consumption maybe happens because the audited enterprise starts to focus on energy efficiency prior to the visit and realise some of the potential savings before the audit actually takes place.

Overall the three graphic exercises do not confirm that a reduction in electricity consumption or just stagnation in consumption takes place after an audit compared to a control group that has not received an audit. The picture is quite unclear. It could be the result of using the annual consumption per employee as explaining factor. However, audited enterprises within 100-200 MWh/year showed a reduction in consumption (relatively and absolutely) after the audit (not taking into account the natural development in the control group). In addition, the greater the identified electricity saving potential in a given enterprise, the greater the realised electricity savings (again, not taking into account the natural development in the control group).

ECONOMETRIC ANALYSIS

Using an econometric regression model the influence of the audit, the enterprise activity level (no. employees), the electricity price, the energy efficiency subsidy scheme, the voluntary agreement scheme, and the audit intensity on the enterprise electricity consumption was investigated. This was done for four lifetime assumptions for the impact of the audits, namely:

1. The audit has only an effect the year of the audit.
2. The audit has the same effect from the year it is carried out and all the following years.
3. The audit has full effect the year of the audit and then the effect diminishes linearly depending on the number of years that has passed since the audit.
4. The audit has full effect in the year of the audit plus the year after.

In an effort to trace an impact of the audits, various subgroups of data were analysed such as energy intensive sites, industrial sites, trade & commerce sites, administration sites, production sites with large recommended investments in energy efficiency improvements, and audit intensive sites.

The complete regression exercise is too complex to include here in detail. The conclusion, however, was that based on the available data set no conclusive impact of the audit activity could be identified. This does not necessarily mean that the audits did not have any effect at all. It simply means that with the data at hand and within the limitations of the project (especially time), it was not possible to determine an impact. With regard to the subsidy for electricity saving initiatives and the voluntary agreements an indication was seen in some of the analyses that the subsidy resulted in a fall in electricity consumption. This effect was, however, only expressed in a small portion of all the estimates of the model and can therefore not be described as stable.

EXPERIENCES / LESSONS LEARNED

With regard to uncertainty the data quality was not as good as expected. The distribution between treatment group and comparison group therefore became uneven. Furthermore, the small number of entities in the sample did not allow detailed branch analyses. One could expect great differences between branches of business but it was not possible to show these.

Moreover the constraints of the project only allowed inclusion of a small number of explanatory variables. Preparing the data material for statistical analysis takes time and cannot be rushed. Evaluation projects should allow sufficient time.

The applied model and graphical analysis did not take into account the possibility of free-riders. Furthermore, the applied approach was able to catch the impact of internal multiplication effects (within the production site) but not external multiplication effects (dissemination to the rest of the enterprise or other enterprises).

It would have been preferable if another indicator for development in activity/production levels could have been tested instead of just the number of employees. Analysis on branch level could to some extent have compensated for the distortions resulting from the use of number of employees as indicator.

Micro-level evaluation

The main objectives of the case study evaluation were to explore the impact and cost-effectiveness, the customer satisfaction, and success/failure factors (see Exhibit 1). In addition, the case studies were to identify positive side effects caused by the audit program such as benefits beyond electricity savings or a higher up-take of other energy efficiency services including those offered on commercial terms.

The case study complemented the statistical analyses very well in that the case study was able to capture the satisfaction and opinions of the customers as well as provide information on economic aspects.

METHOD AND SAMPLING

A sample of ten enterprises, which were extreme, positive examples of successful audits, was selected assuming that if no impact can be found among these enterprises then it is unlikely that other less motivated enterprises will have experienced an impact. Furthermore, the impact experienced in these enterprises can be assumed to be close to the maximum benefit that can be achieved. The resources available determined the size of the sample.

The sample was not intended to be representative for the entire population of audited enterprises. Even so variation in the sample was sought in terms of:

- Type of branch (agriculture, industry, trade and service, public);
- Customer size measured in annual electricity consumption (20-100 MWh/year, 100-500 MWh/year,

>500 MWh/year) assuming that the interest in energy efficiency varies as well as the range of other available offers concerning energy efficiency;

- Organisational set-up of the audit activity of the involved electricity network company (energy centres, transformer stations, outsourcing, electricity/energy audits) assuming that these may differ in resources, concepts, local customer contact;
- Representation of both East and West Denmark due to a historical separation of the two regions.

The final sample was selected in cooperation with the relevant auditors who also provided a copy of the audit report prepared in relation to the audit.

The case study was based on face-to-face standardised, open interviews lasting 1-2 hours. Face-to-face interviews are more costly than telephone interviews but allow capture of vague opinions. A guideline for each interview was developed based on the existing audit report and the information registered in UNITOOL. In each case, both the case enterprise and the associated auditor were invited to comment on the case interview report.

The interview questions related to:

- The preconditions for and experience with energy efficiency improvements;
- The contact between enterprise and auditor;
- Implementation of the recommended energy saving measures;
- Investment costs and savings;
- Strong and weak points in the audit and audit process and suggestions for improvement of the service.

Furthermore, information from databases on energy efficiency subsidies, voluntary agreements, and membership of the A-club were used in the interviews and the following analysis.

The cost-efficiency (input/output) and cost-effectiveness (input/outcome) were calculated from three perspectives, namely the customer, the electricity network company, and societal perspective.

RESULTS

The audited enterprises have in average received 5-6 advices and most of the advices concern lighting and ventilation. Of a total of 56 advices 36 have been implemented. The main reasons for not implementing an advice is lack of economic resources and the advice no longer being relevant. The reasons given for implementing the advices are not only economic but also positive spin-offs and general environmental concern. Typically, the electricity network companies and not the customers initiate the contact.

As expected the implemented measures have a shorter pay-back period than the ones left unimplemented. The average size of the investment, however, does not vary between those implemented and those not implemented.

The customers are overall satisfied with the audit service as could be expected due to the choice of sample. Weak elements listed include lack of communication skills – written as well as oral. Strong point included that the on-site inspection of the auditors was very thorough.

Realised customer investments and savings had to be based on the estimates originally made in the audit reports since no registration of actual investments and savings exists. This places a significant uncertainty on the evaluation results.

Furthermore, a comparison of the historical development in the electricity consumption of the case enterprises with the results of the macro-level evaluation could have been interesting, but was not carried out.

Only three of the ten enterprises use commercial audit services; two of these are energy intensive and use commercial services at regular intervals. For the other enterprises it was important that the audit was free of charge and they are unlikely to seek commercial services.

Only seven of the ten are registered in UNITOOL, which shows that holes in the data to some extent are random.

Half of the enterprises had received a subsidy and three thereof in relation to the audit. Still, only one enterprise attributes the implementation of advice to the availability of a subsidy.

The government uses max. 19 Euro/ton CO_2 saved as a guideline for energy efficiency activities and four of the cases are cost-effective from a societal perspective (see Exhibit 7). If positive side effects on district-heating consumption are included in the calculations then an additional case is cost-effective (last row in Exhibit 7). Seen from a customer perspective, all investments have been paid back within a year – even not including positive side effects such as gas, heat and water savings or improvements in working environment. The given subsidies do not influence the pay-back times significantly.

It is worth noting that some of the implemented advices did not demand investments.

Finally a sensitivity analysis was carried out on the interest rate (+/- 2%points), electricity price (+20%), and lifetime (5 years full effect only). The effect of the variations on the CO_2 shadow prices is shown in Exhibit 7.

Experiences and perspective

The audit program has developed over the years in a dialogue between the electricity network companies, the Danish Energy Authority, the customers and the remaining contexts. Some elements of the program may not seem logical with the eyes of today but are a result of history. As a consequence of the energy market restructuring in Europe, the roles of the market actors have changed, as have their responsibilities. A reassessment of the energy efficiency services provided as public service obligations such as the free-of-charge audits therefore makes sense.

According to the documentation provided by the electricity network companies they fulfil their obligations regarding the audit program. The result of the total audit activity in 2002 was according to the DSM documentation approximately 122 GWh implemented first year savings. The electricity network company cost to achieve this impact was 9 Eurocent/kWh in 2002. The CO_2 shadow price of the planned activity 2003-2004 is expected to be between minus 2.4 EUR/ton CO_2 for industry larger than 500 MWh per

Exhibit 7. *Economic aspects of the audits taking only the electricity savings into consideration (6% interest rate, 15 years lifetime with full effect the first 5 year and then linearly diminishing the following 10 years).*

	Client perspective (EUR)			CO_2 shadow price (EUR/ton CO_2)			
Case enterprises by branch and size (MWh/year)	**Change in electricity bill**	**Investment minus subsidy**	**Net savings**	**NPV**	**Interest rate +/- 2%point**	**Electricity price +20%**	**5 years lifetime**
Agriculture 100-500	-4,916	2,346	2,570	22.4	27.7/17.2	**14.5**	68.9
Industry >500 (a)	Not calculated						
Industry >500 (b)	-68,699	320	68,379	**-34.6**	**-37.1/-38.0**	**-45.6**	**-32.7**
Industry 100-500 (a)	-15,893	9,662	6,231	41.1	47.8/34.4	33.2	100.5
Industry 100-500 (b)	-38,203	6,340	31,863	**-3.6**	**-0.4/-6.7**	**-11.6**	24.9
Trade & service >500	-20,440	10,765	9,675	22.0	27.3/16.9	**14.1**	68.4
Trade & service 100-500	Not calculated						
Trade & service 20-100	-4,544	928	3,616	**6.3**	**10.2/2.5**	**-1.5**	40.9
Public >500	-140,226	7,646	132,580	**-24.6**	**-23.1/-26.1**	**-32.5**	**-10.7**
Public 100-500	-12,496	4,215	8,281	83.7	94.1/73.5	75.5	173.9
Public 100-500 incl. heating	*-21,519*	*4,215*	*17,304*	***10.0***	***18.0/1.9***	-	*81.6*

year and 41.4 Euro/ton CO_2 for agriculture below 100 MWh per year. The case studies show a CO_2 shadow prices ranging from minus 38 to 84 Euro/ton CO_2 over an assumed 15 years lifetime and only counting electricity savings. The government guideline for energy efficiency activities in general is 19 Euro/ton CO_2.

The novelty of the described evaluation was the application of a macro-level statistical approach based on time series of data. Unfortunately the results were inconclusive at best. It can be feared that the lack of significant results could discourage future use of this method.

The data quality was not as good as expected. The distribution between the treatment and comparison group therefore became uneven. Furthermore, the small number of entities in the sample did not allow detailed branch analyses.

It proved very difficult and in some cases impossible to create the necessary time series of data for the statistical analysis. The causes were twofold:

1. UNITOOL does not contain information on the number metering devices numbers, which makes unique identification of the individual enterprises difficult. UNITOOL could be modified to include meter numbers.
2. Market restructuring and changes in accounting systems made older data inaccessible without applying immense work efforts.

In addition, combining databases and data laundry takes time, especially the first time. It could be interesting to repeat the exercise with more time available and see if the statistical analyses could become clearer in their results.

It was far from ideal to use kWh/employee as indicator for the development in energy intensity. Ultimately the choice depended on the databases and the time at hand. Alternatives could have been value added or units produced per year but they also have their weaknesses. Units produced per year as indicator, for example, do not allow comparison across different types of industries.

The micro-level evaluation – i.e. the case studies – had to rely on the audit reports for estimated investments and savings. Metering frequently does not take place on end-use level (but on factory level) and the case studies therefore had to rely on ex-ante engineering estimates of savings made by the auditors. The statistical analysis compensates for this weakness in the case studies, at least in theory but not in reality. In the future it is possible that automatic metering systems will provide access to correct data on annual electricity consumption on end-use level making evaluation easier and results more close to the reality. Another issue was the actual investments made by the enterprises. Again the evaluation had to rely on the preliminary estimates made in the audit reports. Interviews with the 10 case enterprises proved that it often is close to impossible for them to identify the amount that was spent on energy efficiency – the incremental investment costs do not figure in the accounts and can at times be hard to determine if for example the energy efficiency investments are just part of a larger investment in overall improvement or upgrade or expansion of production equipment.

The background evaluation found significant amounts of data missing in UNITOOL, which limits the value of the information contained in UNITOOL. It also showed that the level of detail of the information contained in the DSM documentation and planning reports had changed over the years – for the better – but tracking of the historical development was hampered by the changes. The auditor survey showed an understandable concern regarding cost-effectiveness as a measurement of how well the audit program is being carried out while the electricity companies have to target all customer segments; some less cost-effective than others.

The evaluation applied three different approaches. This proved valuable in the cross checking of information. Furthermore, it made it possible to compensate for flaws in one approach through the information from one of the other. For example, the fact that the regression analysis proved inconclusive was to some extent compensated by the results of the document review and the case studies.

Overall, the use of several different sources of information increased the credibility of the overall evaluation results – The evaluation did not rely solely on the documentation prepared by the electricity network companies and the auditors but also used independent databases and customer interviews. As the biannual DSM-documentation and DSM-plans are a joint effort of all the electricity companies, they are not likely to reflect the span of differences in opinion of

the individual electricity network company. This span was instead investigated through a survey among auditors.

In spite of the problems incurred, it is worth noting that a uniquely great amount of data exists and the framework for maintaining the data is in place. According to the evaluators, it would therefore be worth the trouble to mend the weaknesses and exploit the databases best possible. ELFOR has as a result of the evaluation started validating the historical data in UNITOOL and making sure that all audits are included. Using the information contained in the database actively will as a side-effect encourage the individual electricity company to provide the required data.

References

Summary evaluation report – *Evaluering af elnetselskabernes ikke-kommercielle erhvervsrådgivning*, AKF and SRCI for the Danish Energy Authority, AKF Forlaget, 2004, ISBN:87-7509-782-6.

InterSEE 1998 – *Interdisciplinary Analysis of Successful Implementation of Energy Efficiency in Industry, Commerce and Service (InterSEE)*, Wuppertal Institute for Climate Environment Energy; Energieverwertungsagentur Wien; Frauenhofer Institute for Systems and Innovations Research; Institute for Local Government Studies (AKF); Projekt Klimaschutz, Institute for Psychology (University of Kiel); Amstein & Walthert, EU Joule-III, 1998.

AKF, 2001 – *Energiledelse i dansk industri – kendskab og praksis*, AKF and Advice Analyse for the Danish Energy Authority, September 2001.