ENERGY CONSERVATION (ECON) MODELLING

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1. INTRODUCTION

Oslo Electricity Board's energy conservation program was started in 1982 and it covers all categories of buildings - homes, commercial buildings and industrial enterprises. Our target is to save 10 - 15% of the city's energy consumption (transport excepted) by the year 2000.

Oslo Electricity Board provides grants and loans for consumers who implements special energy conservation measures. The conservation program commenced in 1982 and as of April 1988 we received 6970 applications. Of these were 4826 granted, and 3266 energy conservation projects have been completed.

The procedure followd is that the customers contact an energy conservation consultant who is approved by Oslo Electricity Board. This consultant makes an energy audit of the building and draws up the grant application, cooperating with the building owner. Such surveys are made free of charge, the consultants' fees are paid by the Electricity Board. Conservation measures are grouped in three categories:

1. "A" types of measure: Pay-back in less than two years

2. "B" types of measure: Capital investment cost less than for new firm power

3. "C" types of measure: Support for combined measures up to a given maximum cost, that is to say new firm power.

As a general rule no aid will be granted for type A measures. Measures of type B will receive aid equalling the cost of the measure, provided that all known type A measures have been implemented. In the case of type C measures, the customer must bear the major part of the cost. Financing terms are adjusted so that the saving in energy costs will always be more than the annual outlay on interest and repayments.

Although the number of applications far exceeded our expectations, we managed to give grants and loans according to our budget.

2. PROBLEM OF ESTIMATING NET EFFECT OF OUR ENERGY SAVING PROGRAM

The main problem in this report is to find a method of determining the net saving gained from our ECON program.

It is natural to base the review on factors that affect energy saving, commonly grouped as follows:

(1) Technical measures (insulating etc.)
(2) Creating a positive attitude towards energy saving
(3) Better comfort
(4) Number of persons in occupancy
(5) Prices and incomes
(6) Sundry factors

We are primarily interested in the effect of our ECON program measures have on energy consumption - (the net saving). That is the effect of group 1 Technical measures. The grants application saving figures - anticipated saving - is based on the effect of group 1 only.

The result of meter readings showing the real consumption of electricity, is the effect of all of factors (1) through (6) - the gross saving. In determining the effect of our ECON program, we are faced with a classical problem of identification: The saving recorded is not the saving we are really seeking.

A direct comparison between the anticipated saving and that actually measured, says little about the true effect of the ECON program.

From the gross saving recorded, it should be possible to estimate the impact of factors (2) through (6).

This report presents a system of subsequent analysis in which we try to take the above problems into account. Comfort factors were estimated in advance, using a computer model. The effect of other factors was estimated by using a control group of subscribers to whom a questionnaire was also sent.

3. POST-IMPLEMENTATION ANALYSIS

Post-implementation analysis covers all categories of buildings - homes, commercial buildings and industrial premises. There is not room here to deal with all building categories and I will therefore concentrate on private homes.

The results given below are taken from the residential sector.

There is a contact person for each individual building (the contact person is usually the owner of the building) whose address and telephone number are recorded.

In each case, the individual contact person receives an information letter, a questionnaire and a stamped and addressed return envelope. The questionnaire was prepared on the basis of experience from the phase 1 post-implementation project, and in collaboration with the Central Bureau of Statistics, the Norwegian Institute of Technology, and others.

The design of the questionnaire was intentionally simple to ensure a high response percentage. A graphic artist was responsible for the layout of the questionnaire.

The mailed questionnaire contained the information the Oslo Electricity Board has on: Electricity consumption before and after the ECON campaign and the completion date for the ECON measures. When collecting data, a good deal of telephone contact and reminder letters were required - this applied especially to the multi-family group.

The contact persons were requested to supply the following information:

- Consumption of fuel oil/kerosene and firewood before and after ECON.
- Changes in indoor climate following ECON.
- Has the house been enlarged (or renovated) during the period.
- Heated area before and after ECON.
- Number of residents before and after ECON.
- Has new electrical equipment been installed in connection with ECON measures.

It should be mentioned that, when ECON grants are made, the subscriber agrees that, if selected, he will participate in a survey for recording energy consumption in order to ascertain whether the ECON measures have actually resulted in savings.

MAIN RESULTS

Phase 1

This phase was in the nature of a pilot project and comprised only 50 cases, distributed as follows:

27 single-family houses
18 multi-family houses
5 commercial buildings

Main results:

TABLE 1.1
SINGLE-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction	
		Measured	Anticipated
304 (mean) 58 (st.dev)	217 (mean) 62 (st.dev)	87 29%	105 35%

TABLE 2.1
MULTI-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction	
		Measured	Anticipated
285 (mean) 105 (st.dev)	214 (mean) 57 (st.dev)	71 25%	53 19%

Phase 2

This phase was also in the nature of a pilot project, comprising 117 cases, distributed as follows:

46 single-family houses
36 multi-family houses
35 commercial buildings

Main results:

TABLE 1.2
SINGLE-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction	
		Measured	Anticipated
304 (mean) 71 (st.dev)	232 (mean) 70 (st.dev)	72 24%	97 32%

TABLE 2.2
MULTI-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction Measured	Reduction Anticipated
259 (mean) 95 (st.dev)	225 (mean) 62 (st.dev)	34 13%	41 16%

Phase 3

This phase was an advancement on phase 2, 61 new cases having been added. Distribution was as follows:

76 single-family houses
47 multi-family houses
61 commercial buildings

Main results:

TABLE 1.3
SINGLE-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction Measured	Reduction Anticipated
300 (mean) 82 (st.dev)	223 (mean) 63 (st.dev)	77 26%	90 30%

TABLE 2.3
MULTI-FAMILY HOUSES
Energy consumption in kWh/m2 per annum

Before ECON	After ECON	Reduction Measured	Reduction Anticipated
246 (mean) 96 (st.dev)	211 (mean) 86 (st.dev)	35 14%	39 16%

As far as possible post-implementation analyses are based on the same houses, so that the 50 included in phase 2, are also included in phase 3, and so on.

In general it would seem that the anticipated savings are rather too optimistic.

The divergencies are greatest in the case of single family houses, and are much smaller for multi-family houses. Moreover it must be noted that the divergencies were noticeably smaller in phase 3 than in phase 2 (there were not enough houses in phase 1 to use it for purposes of comparison).

No calculations have as yet been made to estimate errors in measurement, but the following possible sources must be taken into consideration:

- Consumption of oil, wood, coke inaccurately reported by contact person
- Fixed, standardized values were applied for converting to kWh, which means that all stoves/burners are assumed to be equally efficient
- The theoretical real-savings of the ECON measures implemented are only based on measured results to a small extent
- Methods and parameters applied for temperature adjustments

Very few electricity boards are able to make post-implementation analyses based on data for more than one year after the measures were implemented. Therefore the material available is really inadequate for determining whether the difference between measured and anticipated savings is or is not within acceptable margins of error.

A factor that should be examined more closely, is the improved comfort derived with ECON and the bearing this has on the fuel consumption measured afterwards.

From phase 1 we know that the indoor climate is often improved after ECON measures have been put into operation.

If we study the replies to the questions concerning indoor climate after ECON measures have been put in place, we arrive at the following result: 85% state that the indoor climate has improved (43% say a considerable improvement). 15% state slight or no improvement. Normally it is assumed that most of the increase in comfort is in the form of a higher indoor temperature. The problem is: Is the increase in comfort the result of the ECON measures alone? Or: Would this increase in comfort have been realised later anyway, ECON being just an accelerating factor?

<< multi-family buildings, 91% state that the indoor climate had improved, but the response to this question was considerably lower than for one-family houses. Generally speaking, it proved to be more difficult to obtain detailed information from owners of multi-family than from single-family houses.

It was not possible to define the increase in comfort more closely by means of the questionnaire.

4. EDP MODEL FOR DETERMINING COMFORT INCREASE

The questionnaire revealed a clear need for a closer analysis to determine the level of comfort improvements and to ascertain which comfort factors had been changed following ECON measures.

We elected to carry out some trial runs using an EDP (Electronic Data Prosessing) energy model called EGUIDE. This is a simulation model which is normally used to estimate energy consumption before ECON, to suggest profitable ECON measures and to determine energy consumption after ECON.

In collaboration with the consultants responsible for the further development of the model, a special analysis program was selected. Briefly this is as follows:

Firstly, all consumption figures are temperature-adjusted. Subsequently there must be conformity between registered energy consumption and the model's calculated consumption in the situation before the implementation of ECON measures. This is done by amending the following EGUIDE parameters:

- indoor temperature
- number of air changes resulting from planned ventilation
- number of air changes resulting for circumstantial ventilation

Adjustment is assumed to be satisfactory when the divergence between calculated and registered consumption is less than $\pm$ 5%.

A similar adjustment takes place with regard to energy consumption after ECON. The amended parameters are:

- new indoor temperature
- consumption of hot tap water
- changes in electrical equipment having a relatively high energy consumption

The following concepts are then defined in EGUIDE:

Theoretical saving = pre-implementation consumption - post-implementation consumption (not adjusted)

Calculated saving = pre-implementation consumption - post-implementation consumption (adjusted)

Comfort increase = theoretical saving - calculated saving
= post-implementation consumption (adjusted) - post-implementation consumption (not adjusted)

Comfort increase therefore consists of:

(1) Higher indoor temperature
(2) Increase in use of hot tap water
(3) More or increased use of power-consuming electrical equipment

In such analyses it is important that input data are of high quality. In EGUIDE calculations, the client will normally fill out the input form. We worked on the assumption that this a was not sufficiently accurate and an ECON division assistant, therefore, took care of the data collection.

In collaboration with the developers of the EGUIDE system, we agreed that 10 private houses could be a suitable basis for testing the system. Due to inaccurate data, 2 of these houses had to be withdrawn so that the final basis consisted of 8 houses.

The houses in question were selected from those participating in the post-implementation analysis.

The main results are given in the following table:

TABLE 4 (kWh/year)

House no.	Theoretical	Calculated saving	Comfort increase
1	12 601	- 4 162	16 763
2	15 508	5 822	9 686
3	24 235	23 131	1 104
4	15 410	14 628	782
5	16 512	13 889	2 623
6	12 778	2 277	10 501
7	12 942	9 102	3 840
8	32 355	16 446	15 907

It will be noticed that on average the increase in comfort has been considerable, approx. 43% of the theoretical energy conservation.

TABLE 5

Comfort increase divided in calibration parameters (kWh/year):

House no.	Increased indoor temperature	Increased use of hot tap water	Increased use of elec. equipment
1	6 356 (37)	5 606 (33)	4 802 (28)
2	5 317 (53)	2 524 (26)	1 846 (19)
3	543 (49)	325 (29)	235 (21)
4	605 (78)	168 (22)	0
5	1 246 (48)	346 (13)	1 031 (39)
6	5 674 (54)	2 117 (20)	2 709 (26)
7	2 091 (55)	927 (24)	823 (21)
8	4 500 (29)	5 135 (32)	6 272 (39)

The figures in brackets show the share of comfort increase as a percentage of total comfort increase. We see that in most cases a higher indoor temperature represents the largest share of comfort increase. Long winters, relatively low indoor temperature before ECON implementation and lack of campaigning for an "ideal" indoor temperature are the most outstanding explanation factors.

5. WHAT TYPE OF ENERGY CONSERVATION HAS BEEN CARRIED OUT BY THOSE NOT PARTICIPATING IN OSLO ECON

In order to determine the net effect of the measures following the comfort increase, we needed information on the energy-conservation behaviour of those not participating in our ECON program.

To make a study of these conditions, the ECON division carried out two enquiries, one in March 1987 and one in February 1988.

It was found that knowledge of the ECON system in Oslo was fairly constant: In both years 21% replied that they knew about the ECON Fund and/or the grants and loans offered by Oslo Electricity Board.

In 1988 as many as 50% replied that they had taken ECON-type measures, for 1987 the corresponding figure was 63%.

The most common measures in both years, were replacement of windows (26% in 1988 and 21% in 1987) and eliminating drafts (21% in 1988 and 20% in 1987). Only a very few (2 - 6%) had taken more than one type of measure at a time.

Compared with the Oslo ECON scheme, these measures seemed less systematic and coordinated when motivated solely by energy saving. It seems that saving energy is usually not the only motive for taking the measures.

In 1987 about 1/3 of the users had changed to a different fuel (electricity, oil, paraffin, wood) - the corresponding figure for 1988 was 43%. Here it must be emphasized that 1987 was a more normal winter with some very cold periods, whereas 1988 has been extremely mild.

Tendency 1987: Oil consumption unchanged, electricity moderate changes (some reduced, more increased consumption, the majority remained unchanged), paraffin a slight increase and wood a fairly strong increase.

Tendency 1988: Oil consumption unchanged, electricity minor changes, paraffin unchanged and wood down slightly.

Most of these changes are attributed to the new form being easier and providing greater comfort. The mild winter accounts for the lower consumption of wood in 1988, a comment frequently found on the questionnaires.

In both 1987 and 1988 reports, we have registered temperature corrected consumptions figures for the last 3 years.

No reduction in consumption of electricity was recorded for either the whole group or for the group that uses electricity only.

This is fairly surprising considering that relatively many this sub-group took ECON-type measures. In the 1987 survey the standard deviation for consumption of electricity dropped slightly in the last survey year, whereas it rose for the 1988 survey.

For those who use electrical heating and stated that consumption was lower, the results are as follows:

1987: Reduction last year, about 400 kWh
1988: Reduction last year, about 1100 "

For those who have taken ECON-type measures, the reduction in the consumption of electricity is very moderate, about 200 kWh in both surveys (1987 and 1988).

The group that uses electrical heating, has implemented ECON measures and states that electricity consumption is reduced, is very small (5% in 1988 and only 2% in 1987).

Assuming that the replies to the questionnaires are correct, conscious efforts to save energy account for only a fraction of the reduction in consumption. This was particularly noticeable in the 1988 survey.

If we study the change in consumption of wood, a number of interesting factors appear.

For the group now under review (heating by electricity, ECON-type measures effected, and reduction in consumption), 1987 was a somewhat exceptional year. As many as 78% used wood as fuel, although for the whole group this figure was only 49%. When asked how consumption had changed, 46% replied that they used more wood, 19% less, and 35% no change. In the mild 1988 winter, consumption of wood dropped and was comparable with that in the rest of the group. 52% had used less wood, 31% no change, and 26% more wood.

All the same many factors indicate that there was a strong swing towards burning wood in 1987 that might very well explain the registered "savings" gained and more besides. This means that it is unlikely that there is any net saving that is attributable to the ECON-type measures taken.

Conditions in 1988 are more complicated. There was relatively little change in the consumption of the different fuels (electricity, oil etc.), but use of wood was relatively frequent. The group for which electricity is the principal form of heating, have taken ECON measures and reduced consumption, uses as much as 64% wood, whereas those who implemented measures, irrespective of heating and consumption, used only 37% wood. Generally speaking, the ECON measures taken by these two groups were the same. The individual differences consist in that electricity users have concentrated more on saving hot water, rather less on insulation and lower night consumption. In a mild winter the savings may well swing in the electricity user's favour. These conditions may well explain the very moderate savings.

As previously mentioned, it is unlikely that the reduction in electricity consumption did result mainly from the ECON measures. Most of the reduction can be explained by other factors that cannot readily be extracted from the data in this modest survey. However, there are some factors that should be mentioned in this report:

- In a very exceptional winter, simple weather adjustments could give relatively large margins of error.

- With the small sub-groups dealt with here, chance factors may cause extreme effects. (For example, house unoccupied for some length of time, meter-reading errors, change in occupancy etc.). Reduction in energy use may also be due to economies implemented because of changed attitudes, a reason not specified in the questionnaire.

- Changes in financial situation, prices and income fluctuations.

Nevertheless, the main conclusions are clear:

The implementation and results of ECON-type measures effected without the aid of Oslo-Econ do not appear to be very systematic and no real saving can be registered.

whether winters are mild or severe, which may well explain variations in consumption of electricity.

CONCLUSIONS

The ECON program selected by Oslo Electricity Works is dependent on on-going evaluation of the program.

The real net energy savings from ECON are very clear regardless of whether we adjust for increased comfort or not. The control homes showed no savings for the same time period, and therefore the observed savings are due to the program.

It will be an important to conduct further studies on comfort factors susceptible to change. EDP models should be further developed for simplicity of use and for the inclusion of more factors having an influence on increases in comfort.

Future plans include a more detailed study with separate analyses for each sector: residential - industrial - commercial.

Separate yearly goals will be set according to our primary target (1500 GWh).

By combining data from post-implementation analyses and our current statistics, we hope to make more reliable real-saving forecasts. Real-saving figures and forecasts for each sector will be published in our "Monthly Statistics".