RESIDENTIAL ENERGY-EFFICIENT LIGHTING PROGRAMME IN PORI

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ABSTRACT

In this paper, the first utility lighting efficiency programme in Finland is described. The programme was conducted in the city of Pori and 17,000 18-Watt compact fluorescent lamps were given free of charge to residential customers. The delivery of the lamps to the customers took place in less than 2 days. The practical realization was followed by a detailed energy and economic analysis. A comprehensive survey has also been undertaken among the customers to assess the impacts of the programme and to collect practical experiences. It is found that the lamps reduce the peak demand by about 50% of the maximum possible. The effective energy impact fraction of lighting efficiency measures were estimated to be about 60% in the worst case due to the increase of the heating demand when CFLs are used. The utility paid 42 FIM (8.4 ECU) for a single CFL and the survey indicated that a customer would be willing to pay 37 FIM (7.4 ECU), respectively. The analysis showed that the Pori project is profitable both to the customers and national economy, but unprofitable to the utility itself. This is mainly because of the loss of revenues resulting from lower electricity sales.

INTRODUCTION

The City of Pori, located on the western coast of Finland, serves a territory of 80,000 people including heavy industries. The local utility called Porin Energialaitos (Pori energy utility) delivered some 0.4 TWh of electricity and 0.4 TWh district heat to its customers in 1990. The utility produces some 25% of the electricity through its own power plants (e.g., combined heat and power) and the rest is bought from the national grid.

The yearly increase in the electricity consumption during the recent years has been 3-4 % per year but is expected to grow even faster in the coming years. Peak electricity demand is about 100 MW and is reached in mid-December. The peak has grown somewhat faster than total electricity demand. The Pori utility plans its electricity purchase programme a couple of years ahead. The marginal cost of peak power in the winter is some 3.5 times higher than the summertime cost of electricity.

The City of Pori and its utility have considered various new energy technologies for future energy production. New activities and possibilities for using demand-side management to supply more energy services for the increasing electricity demands have been identified. Based on the marginal production cost of electricity, the best economic incentive for energy-efficiency is found in cutting the expensive peak power in December.

A lighting efficiency programme offered one of the best means in cutting the peak in the residential sector. Also, it was possible to reach more easily the customer through a lighting programme and to provide in parallel other information on the utility and energy-efficiency. No doubt, the public relations value of such a programme was valued high, too. A major lighting efficiency programme was incorporated in mid-1990 into the utility's electricity purchase plan and was realized in mid-December the same year. Some 17,000 CFLs (CFL=compact fluorescent lamp) were delivered to customers in Pori within this programme.

In connection with the Pori CFL project, a comprehensive analysis was initiated to evaluate in detail the energy and economic impact of the programme. This included a survey on the experiences among the customers, an in-depth economic analysis from the view-points of a customer, the utility, and the national economy. Also, because the Pori utility has cogeneration of heat and electricity, it was important to estimate the real energy value of the programme, i.e. the effect of CFLs on the total building energy balance. It was expected that a significant fraction of the saved electricity would need to be replaced by additional heat to compensate for a decrease in the internal gains of in the residencies. Lastly, the energy-savings potential from efficient lighting (here: CFL) in Finland was to be estimated.

REALIZATION OF THE CFL PROGRAMME

The programme was realized by a give away-type of approach with no costs for the customers. Only a single CFL type (18W) could be delivered because of a shortage of CFLs in the European market in autumn 1990. The utility purchased altogether 17,000 lamps.

Some 35,000 residential customers were approached through a brochure including a voucher for one lamp free of charge. The information included a short description on the benefits of CFLs. This information was mailed directly to the customers through the information system of the Pori utility. Also, the local newspapers publicized well the Pori lighting programme.

The delivery of the lamps took place at the main and technical office of the Pori utility from three special stands. The customers received the lamp against the voucher. They were asked to fill in their name and address. Information where and how to use the CFLs were also given at these delivery stands. Basically, the 18W CFL corresponded to an ordinary 75W lamp and it was recommended to be installed to a place with a long and steady lighting demand. Initially it was expected that the giving away of the 17,000 lamps would take some 2-3 weeks, but to a great surprise all lamps were handed out in less than two days!

The lamp programme resulted in many inquires concerning energy-efficient lighting and some complaints on running out of free lamps. Less than 100 lamps out of 17,000 turned out to be broken and were replaced.

Some two months after the delivery of the lamps, a questionnaire was sent out to 1000 new lamp owners to find out the experiences and influence of the Pori programme. Also, an objective was to identify which factors influence at most the customer's willingness to buy energy-efficient lighting devices. An important question was to determine the price of CFLs that the market was willing to accept. As a repond, some 600 answers have been received and serve as basis for major findings of this paper. Statistically, the amount of information obtained is adequate to extend the findings to all the 17,000 lamps.

STATISTICAL ANALYSIS

A statistical analysis was made on the 600 answers to assess the influence of the programme as also to collect experiences. As to the background of the consumers, over 80% did not have any prior experiences with CFLs. The CFL lamps were installed as shown in Table 1.

Table 1: Place and time of use of the CFLs in Pori.

Kitchen	47.9%	Evening	54.6%
Corridor	18.3	Morning	35.0
Living-room	16.5	Night	4.7
Outdoors	7.0	All day	2.9
Sleeping-room	5.7	Noon	2.6
Other	4.6	Other	0.2

The use of the CFLs matches well with the peak load in Pori as nearly 90% of the use occurs during the peak demand time. The peak shaving effect is about 60%. Furthermore, the hours used per day vary from less than 2 hours/day up to 9 hours/day. In average, based on the statistical information the lamps are used in average 5.3 hours/day. As the questionnaire was sent out in February during the wintertime, the above figure may be on a yearly basis slightly too high. Compensating for the seasonal variations in daylight availability, an average of 4.4 hours/day may be closer to reality. It was also asked whether the CFL was used more than the replaced lamp and the effect of the replace lamp. It turned out that the customers use in average the CFL 0.8 hours more per day, or when corrected with seasonal effects, 0.7 hours/day. The range of incandescent lamps replaced ranged from 45 to 75 W -- the average was 63 W.

The customers also assessed the characteristics of the lamps (e.g., outlook, size, applicability to fixtures) as also factors influencing their further willingness to purchase CFLs (e.g., price, energy savings). The outcome of this part of the analysis is shown in Figs. 1 and 2. As to the experiences, the consumers were most unsatified with the the size and weight of the CFL. Also, its suitability to existing lighting fixtures was considered poor. On the positive side, the power and light quality as also the durability were mentioned.

SCALE	Look	Size	Power	Light	Weight
1	14	32	3	2	39
2	24	29	4	4	27
3	46	26	25	27	26
4	15	7	51	55	6
5	1	6	17	12	2

Scale from 1=bad to 5=very good

Figure 1: Customer response to the CFLs.

SCALE	Price	Look	Size	Power	Durab.	En. sav.
1	2	6	4	2	1	2
2	6	16	8	5	1	3
3	32	39	29	20	9	13
4	27	30	40	45	33	26
5	33	9	19	28	56	56

Scale from 1=no meaning to 5=very large meaning

Figure 2: Importance of factors affecting the willingness of customers to buy CFLs.

Close to 80% of the customers were willing to buy CFLs by themselves in the near-future. The most important factors affecting the willingness to buy a CFL were directly or indirectly linked to the factors influencing the economics. Such factors were the price of a CFL, its life-time, and energy savings obtained. A further analysis on the price factor showed that a customer was willing to pay in average 37 FIM (7.4 ECU) (price range: 15-120 FIM). The basic information given in the questionnaire sheet on the price question were the cost of a incandescent lamp (5 FIM), yearly savings (30 FIM), and the 5 times longer life-time of the CFL. The required pay-back time was thus around 1 year. Based on their own experience with the CFL lamp, the customers also identified the size and lighting power of the lamps as important factors.

ENERGY ANALYSIS

If the 17,000 CFLs each 18 W replaced a 75 W lamp, the total maximum power effect would be 1 MW. In practice, based on the results of the questionnaire, the practical maximum was 84% of the above figure because of the mix of different lamps replaced (45, 60 and 75W lamps).

The power reducing potential is still reduced by the fact that all lamps are not on at the same time. The best match is in late afternoon and in the evening with about 60% of all lamps in use, and second best in the morning hours with a 35% match. Thus, the maximum power effect in practice turned out to be 0.5 MW (17,000 x (75-18) x 0.84 x 0.60 W), i.e. 50% of the maximum obtainable benefit of the CFL lamps. This is about 0.5% of the peak power demand in Pori, or, about 10% of the yearly increase of the peak.

The average burning time of a CFL in Pori is 5.3 hours/day, or, 1935 hours/year. Accounting for holidays, summertime, etc. may drop that figure. Here we estimate that about 1600 hours (4.4 hours/day) would be closer to the yearly utilization time. The number is slighly higher than that of corresponding Swedish and Danish programmes which partly may be explained by the climatic effects, but also of the location of the lamp that in case of Pori was mainly in the kitchen. The use of day-light in a kitchen may not be adequate even in the summertime and thus requires artifical light explaining thus the higher figure in Finland.

Thus, the total electricity savings obtained per lamp are 72 kWh/year (1600 h x (63-18) W), or, 1224 MWh/year for the total programme.

INTERACTION OF LIGHTING AND HEATING REQUIREMENT IN A BUILDING

The Pori utility provides its customers both with electricity and heat. The customer pays 0.14 FIM/kWh (0.028 ECU/kWh) for district heat and 0.35 FIM/kWh (0.07 ECU/kWh) for electricity. For the utility, marginal production costs are 0.1 FIM/kWh (0.02 ECU/kWh) and 0.16 FIM/kWh (0.032 ECU/kWh), respectively.

Due to the cold climate in Finland, some of the heat produced by lighting during the heating season may directly be utilized for space heating, i.e. lighting is a typical internal heat source. Thus, when applying lighting efficiency one at the same time reduces the amount of internal heat sources and that fraction has to be compensated either through other free heat sources such as solar gains, or, through auxiliary heating.

The effect of lighting to the total building energy balance was investigated by performing building energy analysis with a numerical computer programme. Various building types, lighting levels, thermal insulation levels, and heating modes were studied through hour-by-hour simulations over an entire year. For a single-family house following the Finnish building code, 1 kWh of saved electricity through CFL could in the worst case increase the demand of auxiliary heat by 0.55-0.65 kWh. In the least case, the heat demand increased by 0.3-0.4 kWh for each kWh saved.

In case of an office building with a summertime cooling demand, 1 kWh of savings in lighting electricity, increased the heating demand by 0.3-0.5 kWh depending on the degree of lighting efficiency, but reduced at the same time the cooling load by 0.2-0.3 kWh. The overall savings were the largest for the first kWh so that up to 15% savings in the electrcity use actually gave an over 100% efficiency, i.e. savings through lighting decreased the total heating and cooling demand.

The uncertainities in the interaction between the lighting and the space heating requirement are large and would require experimental verification to give an exact number. This problem diminishes as buildings become more thermally efficient. Also, in terms of primary energy requirements, it would naturally be a wasteful practice to heat buildings using lights.

ECONOMIC ANALYSIS

The success of a lighting efficiency program is in the very end determined by its economics. The overall economics, or, cost-effectiveness may look quite different depending on from what viewpoint it is looked upon. The customer, the utility, and the national economy have different approaches and requirements. Here, we have analyzed the Pori programme in respect to these three different perspectives.

First, we present the major cost factors. A 18 W CFL lamp costs the utility 42 FIM (8.4 ECU) including taxes. The normal retail price is 135 FIM (28 ECU) and sometimes a special price of 99 FIM (19.8 ECU) is offered, too. For reference, an ordinary 75 W light bulb costs 5 FIM (1 ECU) for a customer and 3 FIM (0.6 ECU) for a large customer (e.g. the national economy).

The price of electricity for a customer is 0.35 FIM/kWh (0.07 ECU/kWh) and for a utility 0.16 FIM/kWh (0.032 ECU/kWh). The marginal electricity price nationwide is 0.15 FIM/kWh (0.03 ECU/kWh).

A major concern for a utility arising from a demand-side management programme may be the loss of revenues because of decrease in electricity selling. This is especially the case in which operations of a local utility are mainly financied through electricity trading. For each kWh sold, the Pori utility gets 0.35 FIM/kWh, but pays only 0.16 FIM/kWh, i.e. the net earnings are 0.19 FIM/kWh. To make a lighting programme economically attractive for a utility in Finland, the loss of revenues (here: a maximum loss of 0.19 FIM/kWh, or 0.038 ECU/kWh, is possible) need to be compensated by some ways. The utility could adjust the tariffs to recover the lost revenues but this seems to be a very difficult political question, i.e. through electricity conservation the price of electricity would rise.

The details of the economic analysis are shown in Appendix A. For a 17,000 CFL give away type of lighting programme with above input values, we obtain the following net earnings through one CFL:

- customer	+135.8 FIM (+33.2 ECU)
- utility	-70 FIM (-14 ECU)
- national economy	+31.6 FIM (+6.3 ECU)

It is clearly shown that both a customer and the national economy benefit in this case of an efficient lighting programme, whereas for a utility the outcome was negative. In practice, the utility may have other benefits of introducing energy efficiency, e.g. smaller investments in power lines or PR value, that are more difficult to assess.

In practice, the economic incentive may thus not be strong enough for a utility to realize a lighting efficiency programme with above conditions. Clearly, compensation has to be sought from the consumer and the government. The study indicated that the customer would be willing to pay about 37 FIM/CFL (7.4 ECU/CFL). If the price of a CFL for the customer was thus 37 FIM and the government would provide an additional 33 FIM, the utility would reach a zero level.

Also, it is interesting to note that the maximum acceptable cost for a single customer is equal to the retail price of CFLs today, but some 3.5 times higher than what she/he is willing to pay. A solution to this question may be a direct government subsidy to CFLs as the national economy profits some 31.6 FIM per installed CFL.

The total costs to the utility of the Pori project are about 1 MFIM (0.2 MECU), or, 58.8 FIM/lamp (11.7 ECU/lamp) of which 714,000 FIM (142,800 ECU) where direct costs and the rest 286,000 FIM indirect costs. Much of the indirect costs included promotional work which could be avoided in the future. Thus, net indirect costs were estimated at 120,000 FIM (24,000 ECU). The Finnish government have subsidized the project by 480,000 FIM (96,000 ECU).

The overall societal cost of conserved energy (real discount rate 6%) of the Pori project as today is 0.18 FIM/kWh including taxes (0.04 ECU/kWh). For future projects, a total CCE of 0.12 FIM/kWh (0.024 ECU/kW-h) is envisioned.

POTENTIAL OF CFLS IN FINLAND

The total electricity use through incandescent lamps in Finland in 1988 was 2050 GWh of which residential buildings accounted for 56%, the service sector 35%, and the industrial use for the remaining 9%. These figures also are the gross potential for CFLs in Finland. A saving of 2 TWh by more efficient lighting would increase the heating demand by about 1 TWh. For comparison, the total electricity use in Finland was 60 TWh.

CONCLUSIONS AND RECOMMENDATIONS

The overall experiences of the Pori CFL project have been positive and the goals have been achieved. The project has given valuable practical information on how to plan and realize a lighting efficiency programme in utility scale. Also, important response from the customers have been received.

The following main conclusions may be drawn:

- the net impact on power is 50% of the nominal power savings
- saved electricity increases the residential heating demand
- under current rules, a give away type programme is unprofitable for a utility
- a give away CFL programme is profitable to a customer and the national economy
- the average willingness-to-pay price of a CFL is 37 FIM (7.4 ECU)
- a give-away type of programme may be realized in a very short time
- a customer gives much attention to factors affecting cost-effectiveness
- proper lamp size and shape are important

- 80% of the participants would be willing to buy CFLs in the future

Based on these findings, we make the following recommendations for further programmes:

- include different types (size, Watt) of CFLs to a programme
- joint financing by customers and authorities should be considered
- dissimination of information on CFLs to customers is important

APPENDIX A Economic analysis for different sectors

1. CUSTOMER (1 CFL)

Energy savings per year (63 W - 18 W) x 1600 h	72 kWh/year
Money saved per year 72 kWh/year x 0.35 FIM/kWh	25.2 FIM/year (5 ECU/year)
Energy-savings over life-time (63 W - 18 W) x 8000 h	360 kWh
Money saved over life-time 360 kWh x 0.35 FIM/kWh	126 FIM (25.2 ECU)
Increased heating demand 0.6 x 72 kWh/year	43.2 kWh/year
Heat cost over life-time 5 years x 43.2 kWh/year x 0.14 FIM/kWh	30.2 FIM (6.1 ECU)
Money saved in investments for incandescent lamps 8 x 5 FIM	40 FIM (8 ECU)
Total savings per CFL	**135.8 FIM (33.2 ECU)**

2. ELECTRIC UTILITY (17,000 CFLs)

Earnings

Energy savings per year (63 W - 18 W) x 1600 h x 17000	1,224,000 kWh/year
Money saved per year 1224 MWh/a x 0.16 FIM/kWh	195,840 FIM/year (39,168 ECU/year)
Savings in power (75 W - 18 W) x 0.5 x 17000	484.5 kW
Money saved through power 484.5 kW x 233 mk/kW,year	112,889 FIM (22,578 ECU)
Total savings per year 195,840 FIM + 112,889 FIM	308,729 FIM (61,746 ECU)
Loss of yearly revenues 1,224 MWh x 350 FIM/MWh	-428,400 FIM (85,680 ECU)
Increase in district heat sale 734 MWh x 40 FIM/MWh	+29,360 (5,872 ECU)
Net loss due to decrease in electricity sales -428,000 FIM + 308,729 FIM +29,360 FIM	-89,911 FIM (17,982 ECU)
NPV of the loss (over 5 years, i=6%)	-358,133 FIM (71,627 ECU)

Investment

Direct costs (CFLs) 42 FIM x 17,000	714,000 FIM (142,800 ECU)
Indirect costs	120,000 FIM (24,000 ECU)
Total costs	834,000 FIM (166,800 ECU)

Total loss -358,133 FIM - 834,000 FIM	-1,192,133 FIM (238,427 ECU)
Total loss per CFL	**70 FIM (14 ECU)**
Total loss including subsidy	-712,133 FIM (142,427 ECU)
Total loss per CFL including subsidy	**41.9 FIM (8.4 ECU)**

3. NATIONAL ECONOMY (17,000 CFLs)

Earnings

Energy-savings per year (63 W - 18 W) x 1600 h x 17000	1,224,000 kWh/year
Money saved per year 1224 MWh/year x 0.16 FIM/kWh	195,840 FIM/year (39,168 ECU/year)
Increase in heat demand 0.6 x 1224 MWh/year	734.4 MWh
Heat cost per year 734.4 MWh x 100 FIM/MWh	73,440 FIM (14,688 ECU)
Savings in power (75 W - 18 W) x 0.5 x 17000	484.5 kW
Money saved through power 484.5 kW x 233 mk/kW,year	112,889 FIM (22,578 ECU)
Total savings per year 195,840 FIM + 112,889 FIM -73,440 FIM	235,290 FIM (47,058 ECU)
NPV of the savings (over 5 years, i=6%)	991,104 FIM (198,208 ECU)
Investment of ordinary bulbs 160,000 x 3 FIM	380,000 FIM (76,000 ECU)
Total earnings	1371,104 FIM (274,221 ECU)

Investment

Direct costs (CFLs) 42 FIM x 17,000	714,000 FIM (142,800 ECU)
Indirect costs	120,000 FIM (24,000 ECU)
Total	834,000 FIM (166,800 ECU)
Total savings 1371,104 FIM - 834,000 FIM	537,104 FIM (107,421 ECU)
Total savings per CFL	**31.6 FIM (6.3 ECU)**