

LOAD-SHAPE DATA FOR RESIDENTIAL LIGHTING: SURVEY RESULTS FOR INCANDESCENT AND COMPACT FLUORESCENT LAMPS.

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Abstract

Knowledge of the load pattern of compact fluorescent lamps (CFLs) is important in order to evaluate the impact on system load and to calculate the energy savings.

Following a CFL give-away programme by the Danish utility SEAS a survey was made. The main purpose of the survey was to map the daily patterns of use of the CFLs, as well as incandescent lamps in the residential sector throughout the year. A secondary aim was to evaluate consumers acceptance of the CFLs.

A total of 120,000 residential consumers were given 2 CFLs each, of which they were actually able to use 90% (1.8 CFLs per home). This represent only 7% of the total number of lamps per home. The survey showed, however, that the CFLs have long burning hours accounting for nearly 20% of the total burning time of all lamps. Consequently the savings in electricity consumption for lighting due to the CFLs is approximately 15% or 125 kWh per home.

During the afternoon peak hours on winter days it is found, that up to 80% of the CFLs will be in use. During the morning peak hours, however, only approximately 30% of the CFLs are burning.

The accuracy of the method as well as alternate methods of lighting load analysis are briefly discussed in this paper.

Introduction

Since 1988 Danish utilities have run a variety of programmes to promote the use of compact fluorescent lamps (CFLs) mainly in the residential sector^{1,2}

The largest programme has been the give-away programme by SEAS in early autumn 1989. SEAS is a distribution company which serves approximately 120,000 residential consumers on Zealand south of Copenhagen. The peak load is in the order of 500 MW.

Each residential consumer was given 2 Philips CFLs: a 13 Watt type SL, and a 11 Watt electronic type PLC. Consumers were encouraged to put the lamps in places where they would be used during peak hours.

In order to investigate the lighting load curve, and especially the pattern of use of the CFLs, four surveys by questionnaire were made in the period from November 1989 to May 1990. DEFU designed the survey experiment and analysed the results. SEAS selected the consumers for the survey and posted the questionnaires. The research project was financed by ELKRAFT and ELSAM.

The survey

The background, the method of survey and the results are reported in detail elsewhere³.

The method of survey by questionnaires had been used previously in the EFFE project, ⁴ with success. The sample was comprised of 2400 consumers, and yielded a response rate of 70%. This was viewed as very satisfactory. The survey yielded only load curves for one month (November), however, and in the SEAS survey, the aim was to establish load curves for week-days throughout the year. This was done by sending questionnaires 4 times in the winter 1989 and spring 1990 (Table 1) and assuming seasonal symmetry (i.e. autumn months correspond to spring months).

At the same time the supply area and number of consumers which had been given CFLs was much larger (50 times) in the SEAS project than in the EFFE experiment. This also made SEAS an interesting area to study.

electricity consumption for lighting varied from 550 kWh to 980 kWh per year and home (Table 3). The consumption was calculated on the base of the load curves described later in the report.

Table 3: Average number of lamps per home.

No of lamps in:	Single-family house	Multi-family house	Farmhouse
Main room	7	5	7
Kitchen	4	3	4
Bath	2	1	2
Hall etc.	3	2	3
Other rooms	6	3	5
Outdoor	2	1	2
Misc.	2	1	5
Total	26	16	28
Consumption^{*)}			
kWh/year	850	550	980
kWh/year/m ²	6.3	6.7	6.0

^{*)} Assuming incandescent lamps + existing CFLs.

Consumers could use 88% of CFLs given to them under the SEAS programme and an additional 2% were placed in second houses or given away. Lack of suitable fixtures were the main reason that consumers were unable to use all CFLs. Most of the CFLs were placed in the main room (55%) and in the kitchen (20%). See table 4.

Table 4.: Use of CFLs (type SL and PLC).

Type of dwelling:	Single-family house		Multi-family house		Farmhouse	
	SL%	PLC%	SL%	PLC%	SL%	PLC%
Room:						
Main room	52	53	60	66	38	56
Kitchen	21	19	20	9	25	14
Bath	0	1	3	2	0	1
Hall etc.	6	10	7	9	11	10
Other rooms	3	4	7	11	3	4
Outdoor	14	12	3	3	18	11
Misc.	4	1	0	0	5	4
Total	100	100	100	100	100	100

The number of annual hours of operation of the CFLs were found to be high, ranging from 1600 hours per year in single- and multi-family houses to 1900 hours per year in farmhouses. The number of hours of operation per CFL drops as the number per home increases. Eventually this will reach the average of all lamps (approximately 600 hours) or lower. The average wattage of the incandescent lamps, which the CFLs replaced, ranged from 52 to 61 Watts.

Twenty percent of the consumers said that the CFLs were operated longer than the incandescent lamps they replaced. Less than five percent said they operated shorter. A control calculation shows, however, that there was little difference between the burning hours for the group which indicates prolonged burning time and the rest: Both groups operated their lamps approximately 7 hours per day during mid winter period and 3 hours per day in May.

The 1.8 CFLs per home represent only 7% of the total number of lamps per home. Calculations based on the use throughout the days and year show, however, that the CFLs account for 20% of the total operation hours of all lamps. The savings in electricity consumption for lighting due to the CFLs are approximately 15% or 125 kWh per home in the SEAS area.

Consumers were also asked how many CFLs they possessed prior to the SEAS give-away, and how many more CFLs they thought they could use in existing fixtures.

The average was a total of 5.3 CFLs in single-family and farmhouses and 3.6 in multi-family houses. The figures include all possible CFLs, i.e. existing (in average 0.3 CFLs per home), SEAS give-away and future CFLs. Figure 2 illustrates the possibilities in single-family houses.

Single-family houses

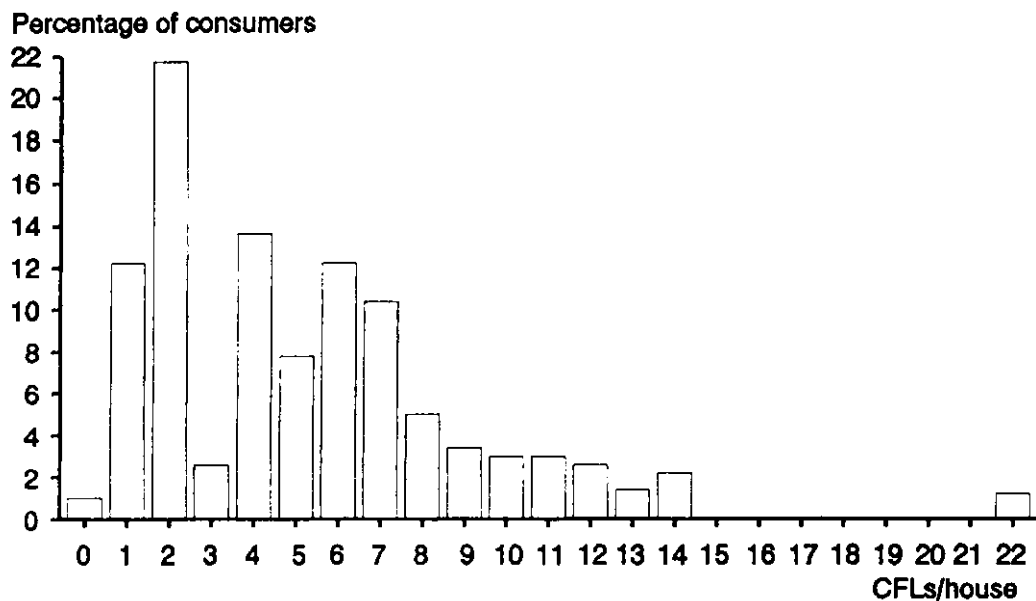
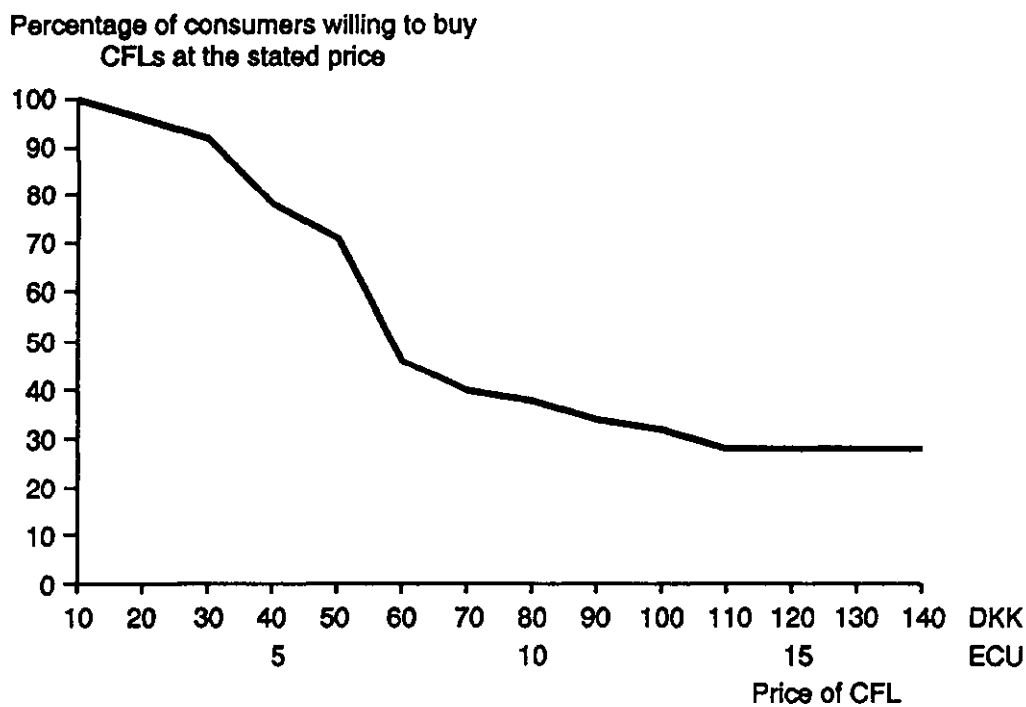


Figure 2: Max number of CFLs, existing fixtures.

One percent of the consumers will not be able to use any CFL, twelve percent to use 1 CFL etc.

Thirty percent of the consumers indicate that they are willing to buy CFLs at their own expense at the price level at time of the survey, 150 - 250 DKK (20 - 30 ECU). The price, however, should be lowered to approximately 40 - 50 DKK (5 - 6 ECU) to make it acceptable to the majority of consumers (Figure 3).



Load curves

Daily load curves based on the questionnaires were established for incandescent lamps and the CFLs throughout the year assuming sinusoidal variation with the season--i.e. natural light conditions--plus a constant load, which appears to fit well with the observations. Results are given in Watts per home; in number of lamps "on" per home, or as load factors (l.f.) defined as the number of lamps "on" divided by the total number of lamps. Whatever units adopted in the presentation, can easily be converted assuming appropriate wattage per lamp.

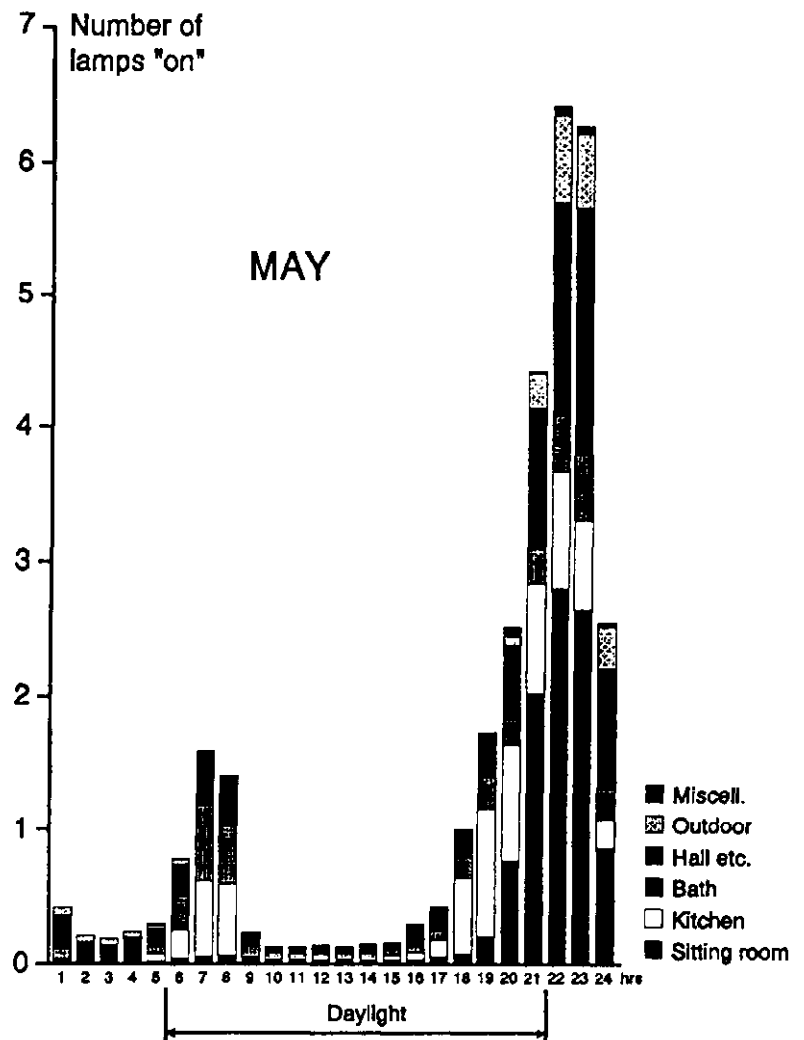


Figure 4: Single-family house. All lamps.

Figure 4 shows a typical May-curve, with specification of lamps "on" in the various rooms of the house.

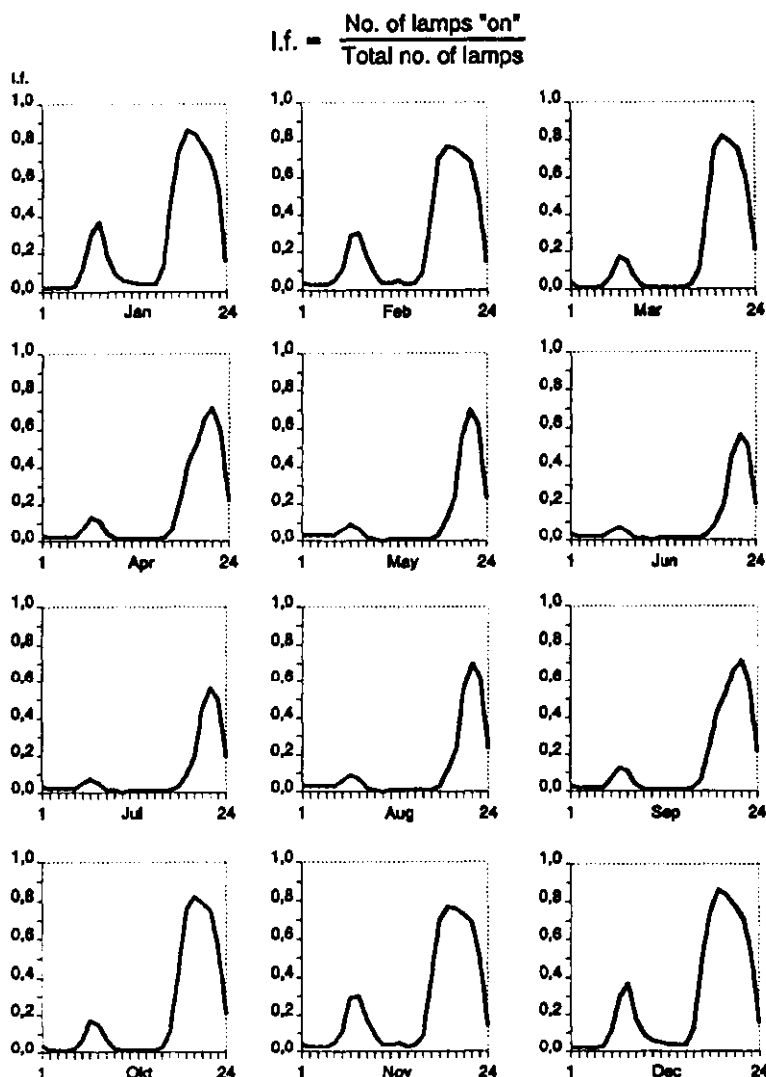


Figure 5: Load curves, CFLs single-family houses.

Figure 5 shows load factors (load curves) for the 1.8 CFLs, one curve for each month. During afternoon peak hours on winter days approximately 80% of the CFLs will be in use. During morning peak hours only approximately 30% of the CFLs will be operating. In summer values are substantially lower. Loads in W, kW and MW are obtained by multiplication with the appropriate number of lamps and wattages. It should be noted, that the load factors will decrease if the number of CFLs per home is increased (cf. later, Figure 6).

Accuracy of the method

Obtaining reliable data on the electricity consumption for lighting and particularly load curves is a difficult task^{3,5,6}. The results obtained with the method described above differ from previous estimates for Danish conditions. The energy consumption per year is found to be 10-18% higher than the former estimates and the load curves generally show a higher load in summer and on mornings than previous curves³.

The earlier estimates were based on the "residual method" and--as far as the energy is concerned--also on the well known "sales and stock" method cf.⁵. The latter method, however, we have found rather dubious for Danish conditions due to the difficulty of separating lamps sold for private homes and lamps sold for the commercial sector. Hence we have more faith in the questionnaire method although it has some potential weaknesses:

- 1) Are consumers in the survey representative? We know they are representative as to size of dwelling, and the number of persons per dwelling but perhaps the behavior of our sample differs from that of the population's?
- 2) Are the answers given to the questionnaire correct, or are they biased?

Tests have shown that the answers are not influenced by the examples--on how to fill in the questionnaire--enclosed. We have also found good agreement between the results in SEAS's service area and the previous survey in the EFFE area (Figure 6). Load factors are slightly lower in the EFFE area due to a larger number

3) The survey did not include weekends and holidays. This would have increased the budget of the experiment substantially. A rough correction has been made but this could still be a reason for an overestimate.

Single-family houses. November.

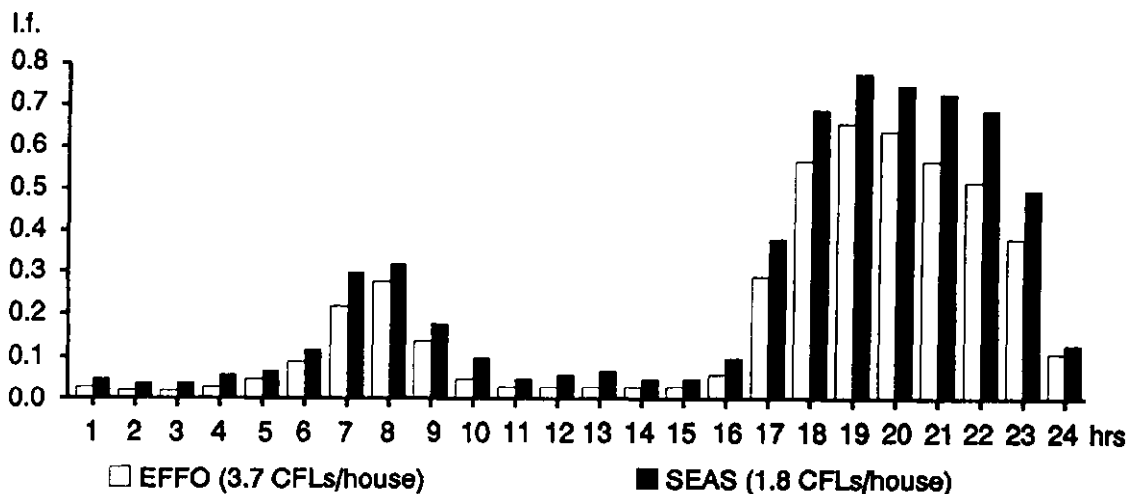


Figure 6: Comparison of EFFO and SEAS survey.

Various other methods include direct recording on lamps in a house, which was actually done in one experiment⁴. The cost of using this method on a large scale is prohibitive.

Measuring the effect at the system level is not practical. Even in an project as large as the SEAS programme, with 1.8 CFLs per home, the effect of the 0.22 million CFLs is 8-9 MW which, unfortunately, is within the "noise level" in a system with daily peak loads of 400-500 MW in winter [Figure 7].

Wednesday, 21. november 1990

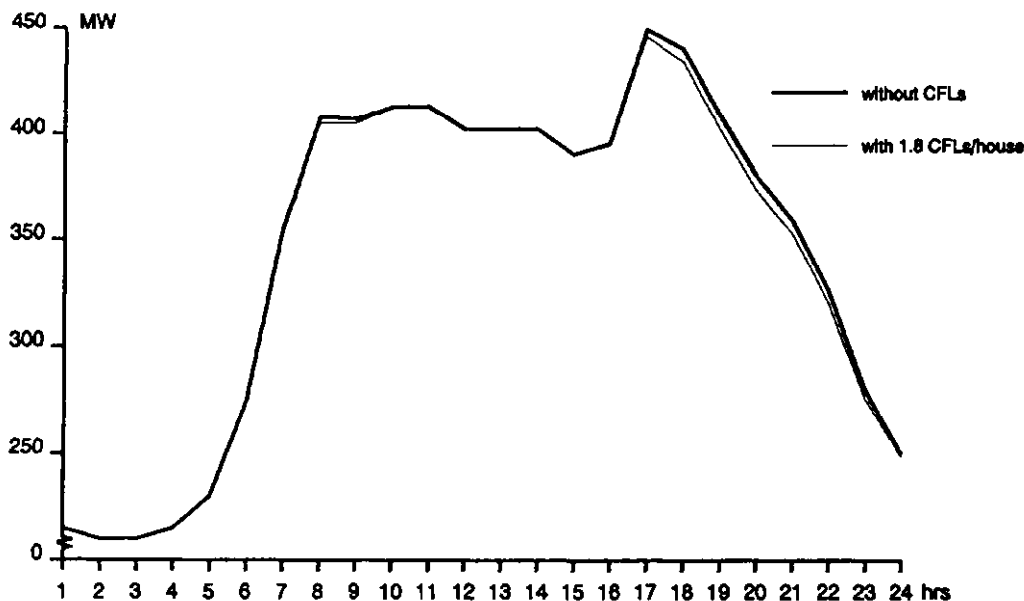


Figure 7: Total load SEAS.

Further recordings on low voltage feeders for residential areas combined with interviews and recordings on house level could be one way of improving load data for homes.

Conclusion

The Danish utility SEAS has conducted the largest European programme to promote compact fluorescent lamps (CFLs). The programme achieved a 90% participation rate and 240.000 lamps were given away.

A household survey following the programme provided useful information on the way households use the energy-efficient lamps. Consumers respond favorably when advised to use CFLs during the time of the utility's system peak. As a result, programme was effective at saving energy and at reducing utility peak load. The survey method appears to give more reliable data than does previously used methods.

Because consumers chose high-use sockets, installing an average of 1.8 CFLs/household result in a 20% reduction of household electricity use for lighting. Further savings are achievable, because the average household reports being able to use a total of 5 CFLs.

References

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