

## **A SIMPLIFIED LIGHTING AUDIT PROCEDURE FOR SCHOOLS**

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### **Abstract**

To encourage implementation of energy-efficient lighting systems The Danish Energy Agency has funded a project concerning Right and Energy-Efficient Lighting in Schools. The project is performed as a joint effort between Light & Optics and The Danish Illuminating Engineering Society.

The main result is a booklet addressing schools, municipal authorities, regional administrations and advisors in lighting or energy consumption. Additionally, a supporting report has been issued.

The booklet, printed in 10,000 copies, informs about the functional demands and explains about lighting quality and requirements. A standardized energy audit form facilitates determination of power, annual energy consumption and potential savings. The booklet is intended to establish the basis for qualified decisions about whether to retrofit the lighting installation. Solutions showing alternative lighting systems and their economy are not included in the booklet.

### **Background**

Research carried out in recent years has demonstrated a lack of quality in many lighting systems as well as excessive energy consumption. This is in spite of new technologies for improving energy efficiency which yield more light for less money and energy - and often at the same time achieve higher lighting quality. Projects carried out in Denmark have estimated that in schools energy consumption can be more than halved from an annual power level of 330 GWh to approximately 130 GWh.<sup>3</sup>

### **The Project**

To communicate information, overcome barriers and promote knowledge of energy-efficient high quality lighting, Light & Optics has completed a project in cooperation with The Danish Illuminating Engineering Society. The project was financed by The Energy Agency in Denmark.

As a result of this project, a booklet addressing schools, municipal authorities, regional administrations and advisors in lighting or energy consumption was written and published<sup>1</sup>. A comprehensive, supporting report for people with more detailed interest or specific knowledge has been issued as well<sup>2</sup>.

### **The Booklet**

The booklet<sup>1</sup> has been sent without charge to approximately 4,500 schools and educational establishments in Denmark. Ten thousand copies were printed. Next autumn municipal authorities and regional administrators will receive the booklet enclosed a folder describing the key-figures of a renovation implemented in a Danish School.

The booklet ends up with evaluation of energy efficiency, lighting quality, and possible savings. Hereby it forms the basis for well-founded decisions whether to renovate the lighting system or not. Before taking further actions the economical consequences of renovating the lighting installations must be studied. Such considerations are not included in the booklet. Methods to calculate annual expenditure and pay-back time for alternative lighting systems can easily be found elsewhere<sup>5</sup>.

### ***Functional demands and lighting requirements***

The text informs in plain words about the functional demands and lighting requirements at different locations in a school such as: Outdoor areas, bicycle basement, staircases and corridors, normal classrooms, rooms for art,

drama, needlecraft, woodwork, domestic science, EDP, physics, biology, chemistry, as well as sportscentre or gymnasium, toilets and locker room, canteen, library and offices.

Additionally, more specific data comprising illuminance in lux, glare limit for the general lighting, recommended power consumption in  $W/m^2$  recommendable light sources and fittings and special notes or requirement e.g. special light on the black-board are given for each location. Reference is made to fig. 1.

| BOX FOR                          | Normal classrooms  |
|----------------------------------|--|
| Illuminance                      | 200 lux in general lighting and 500 lux on the black-board   |
| Glare limit for general lighting | M  |
| Power consumption                | 10 W/sq.m incl. light on the black-board   |
| Light sources                    | General lighting: compact fluorescent lamps or fluorescent tubes.<br>Black-board lighting: fluorescent tubes                             |
| Lighting fixtures                | General lighting: fixtures for lighting tubes on the ceiling or lowered, pendants for compact fluorescent lamps, HF-ballast if possible. |
| Black-board lighting             | Special fixtures with asymmetric light distribution.   |

Fig. 1: Example of the box used to demonstrate the guidelines and recommendations in a school<sup>4</sup>. The boxes, one for each location, are highlighted in the booklet. The above is taken from the section dealing with a normal classroom.

*The standardized energy audit form to calculate energy consumption and potential savings.*

For practical use in a particular school, a standardized energy audit form is included. For the first time in Denmark recommendations for the required total power consumption in  $W/m^2$  in different areas of the school are provided. The recommended figures, shown in fig. 2, column 8, include general lighting as well as local lighting on black-boards, machines etc. This facilitates determination of actual and recommended total annual electricity consumption for lighting purposes. As a result a list of priority related to energy savings can be set up with ease.

The standardized energy audit form, shown in fig. 2, is intended to be used by people without special knowledge of lighting.

Records for an existing lighting installation is stated in fig. 3. For a normal classroom the example gives a possible reduction in power of 62% (from  $26.5 W/m^2$  to  $10 W/m^2$ ), which for an estimated working time of 1000 hours/year equals an annual saving of  $16.5 kWh/m^2$ . For 10 classrooms with a total floorage of  $680 m^2$  this means a possible reduction from  $18,020 kWh/year$  to  $6,800 kWh/year$  or savings up to  $11,220 kWh/year$ . Provided a users price of  $0.95 D.kr./kWh$  the potential saving is  $D.kr. 10,659$  or approx. ECU 1,345 per year.

### The Supporting Report

The comprehensive report<sup>2</sup> describes the whole project, starting with early literature and investigations in schools<sup>6</sup>, lighting guidelines<sup>4</sup>, functional demands, lighting recommendations and considerations in connection to the recommended power consumptions. Calculated economical consequences of a fictional renovation of the lighting system in a classroom-recorded and shown as an example in fig. 3-is provided in the report. Calculations for alternative lighting systems fulfilling all guidelines show pay-back times of approx. 3 years for a simple solution and 8 years for a more advanced one.

### Future Aspects

Hopefully, the booklet will diminish the uncertainties many people have about the link between quality of light and energy consumption. Using the standardized energy audit form to assess the lighting system of a school can easily start important discussions among teachers, caretaker, headmaster, school board and outside persons dealing with economy and maintenance in relation to the lighting environment in the school.

It is expected that the procedure used in the booklet-a simple text to define and explain the lighting requirements and a standardized form to calculate energy consumption and potential savings-will be used in a series of new projekt concerning different working premises. The Danish Energy Agency has just granted the first project in the row, being "Right and Energy-Efficient Lighting in Offices".

### References

- [1] Vibeke Clausen & Poul Kattler, 1990. God og energirigtig skolebelysning (A booklet: Right and Energy-Efficient Lighting in Schools). Light & Optics and The Danish Lighting Society, Denmark. (In Danish)
- [2] Vibeke Clausen & Poul Kattler, 1990. God og energirigtig skolebelysning (A report: Right and Energy-Efficient Lighting in Schools). Light & Optics and The Danish Lighting Society, Denmark. (In Danish)
- [3] Poul Erik Pedersen, 1988. Vurdering af elbesparelspotentialer på belysningsområdet. (Evaluation of potential lighting electricity saving). The Information Service of Light & Optics, Note No. 257, Lyngby, Denmark. (In Danish)
- [4] DS700 - Retningslinier for kunstig belysning i arbejdslokaler, 4. udg. 1986. (Guidelines for artificial lighting in working premises, 4th edition). Dansk Standardiseringsråd, Copenhagen, Denmark. (In Danish)
- [5] Lysteknisk Selskab, 1987. Det betaler sig at se på lyset -hvordan? (Looking into the light pays of - But how?), The Danish Lighting Society, Stenløse, Denmark. (In Danish)
- [6] Gunnar Gjelstrup, Jens Gudum, Helle Trøst Nielsen, Muligheder for elbesparelser, forsøgsnotat nr. 2. (Possibilities for lighting electricity savings, Research-Note no. 2), AKF, Denmark. (In Danish)

| Locality                  | Recorded total wattage per room (W) | Floors per room (m <sup>2</sup> ) | Number of rooms alike | Annual working time in h | Total area in the school in m <sup>2</sup> | Power consumption in W/m <sup>2</sup> |             |        | Annual energy consumption in kWh/year |             |        | Recommended lighting level in lux (according to the Danish Lighting Guide, DS700) | Measured or calc. light level in lux |
|---------------------------|-------------------------------------|-----------------------------------|-----------------------|--------------------------|--|---------------------------------------|-------------|--------|---------------------------------------|-------------|--------|---|--------------------------------------|
|                           |                                     |                                   |                       |                          |  | Actual                                | Recommended | Saving | Actual                                | Recommended | Saving |   |                                      |
| 1                         | 2                                   | 3                                 | 4                     | 5                        | 6  | 7                                     | 8           | 9      | 10                                    | 11          | 12     | 13  | 14                                   |
| Bicycle basement          |                                     |                                   |                       |                          |  |                                       | 2           |        |                                       |             |        | 50  |                                      |
| Staircases/corridors      |                                     |                                   |                       |                          |  |                                       | 4           |        |                                       |             |        | 50/100  |                                      |
| Normal classrooms         |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | 200   |                                      |
|                           |                                     |                                   |                       |                          |  |                                       |             |        |                                       |             |        | black-board   | 500                                  |
| Art/drama                 |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | Art/general   | 200                                  |
| Needlecraft               |                                     |                                   |                       |                          |  |                                       | 25          |        |                                       |             |        | Drama/general   | 50/200                               |
| Woodwork                  |                                     |                                   |                       |                          |  |                                       | 15          |        |                                       |             |        | Bl. board/gen.  | 500/200                              |
| Domestic science          |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | gen./bl. board  | 200/500                              |
| EDP                       |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | general/desks   | 50/200/500                           |
| Physics/biology/chemistry |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | General/monit   | 50/200                               |
|                           |                                     |                                   |                       |                          |  |                                       | 12          |        |                                       |             |        | Black-board   | 500                                  |
| Sports centre/gymnasium   |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | gen./bl. board  | 0/200/500                            |
| Toilets/locker room       |                                     |                                   |                       |                          |  |                                       | 4-8         |        |                                       |             |        | general   | 50/200                               |
| Canteen                   |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | general   | 100/200                              |
| Library                   |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | gen./examen   | 50/200                               |
|                           |                                     |                                   |                       |                          |  |                                       | 10          |        |                                       |             |        | cooking   | 500                                  |
| Office                    |                                     |                                   |                       |                          |  |                                       | 8           |        |                                       |             |        | gen./back of  | 200                                  |
|                           |                                     |                                   |                       |                          |  |                                       | 8           |        |                                       |             |        | Books/reading   | 500                                  |
|                           |                                     |                                   |                       |                          |  | Total lighting energy in kWh/year     |             |        |                                       |             |        | Electricity costs:  |                                      |
|                           |                                     |                                   |                       |                          |  |                                       |             |        |                                       |             |        | _____ D. kr./kWh or   |                                      |
|                           |                                     |                                   |                       |                          |  |                                       |             |        |                                       |             |        | _____ ECU/kWh   |                                      |

Fig. 2: A standardized energy audit form for laymen to identify potential savings in power consumption in lighting systems in schools.

| Locality          | Recorded total wattage per room (W) | Floorage per room (m <sup>2</sup> ) | Number of rooms alike | Annual working time in h | Total area in school in m <sup>2</sup> | Power consumption in W/m <sup>2</sup> |             |        | Annual energy consumption in kWh/year |             |        | Measured or calc. light level in lux               |     |
|-------------------|-------------------------------------|-------------------------------------|-----------------------|--------------------------|--|---------------------------------------|-------------|--------|---------------------------------------|-------------|--------|--|-----|
|                   |                                     |                                     |                       |                          |  | Actual                                | Recommended | Saving | Actual                                | Recommended | Saving |  |     |
| Column 1          | 2                                   | 3                                   | 4                     | 5                        | 6                                      | 7                                     | 8           | 9      | 10                                    | 11          | 12     | 13   | 14  |
| NORMAL CLASSROOMS | 1800                                | 68                                  | 10                    | 1000                     | 680                                    | 26.5                                  | 10          | 16.5   | 18,020                                | 6,800       | 11,220 | 200  | 105 |
|                   |                                     |                                     |                       |                          |  | Total lighting energy in kWh/year     |             |        |                                       |             |        | Users price of electricity:<br>D.kr/kWh or ECU/kWh |     |
|                   |                                     |                                     |                       |                          |  | Total lighting energy in ECU/year     |             |        | 2,162                                 |             |        | 0.12   |     |

Column 2: The lighting installation consists of 12 luminaires each supplied with a 150W incandescent lamp. Recorded total wattage: 1800 W

Column 3: Floorage per room: 68 m<sup>2</sup>

Column 4: Identical classrooms: 10

Column 6: Total floorage: 10\*68 m<sup>2</sup> = 680 m<sup>2</sup>.

Column 5: Interviewing the headmaster, teachers and caretaker indicates a yearly working time of approx. 1000 hours, corresponding to a average of 5 hours a day in 200 days a year.

Column 7, 8 and 9:

The actual power consumption is 1800 W/680 m<sup>2</sup> = 26.5 W/m<sup>2</sup>. Compared to the recommended power consumption of 10 W/m<sup>2</sup> it indicates savings up to 16.5 W/m<sup>2</sup> may be achieved. Use of incandescent lamps causes excessive energy consumption.

Column 10, 11 and 12:

The total actual energy consumption:  
1000 hours/yr\*680 m<sup>2</sup>\*26.5 W/m<sup>2</sup>/1000 =

18,020 kWh/yr or 2,162.40 ECU/year

The total recommended energy consumption:

1000 hours/yr\*680 m<sup>2</sup>\*10 W/m<sup>2</sup>/1000 =

6,800 kWh/yr or 816.00 ECU/year

The total potential savings are:

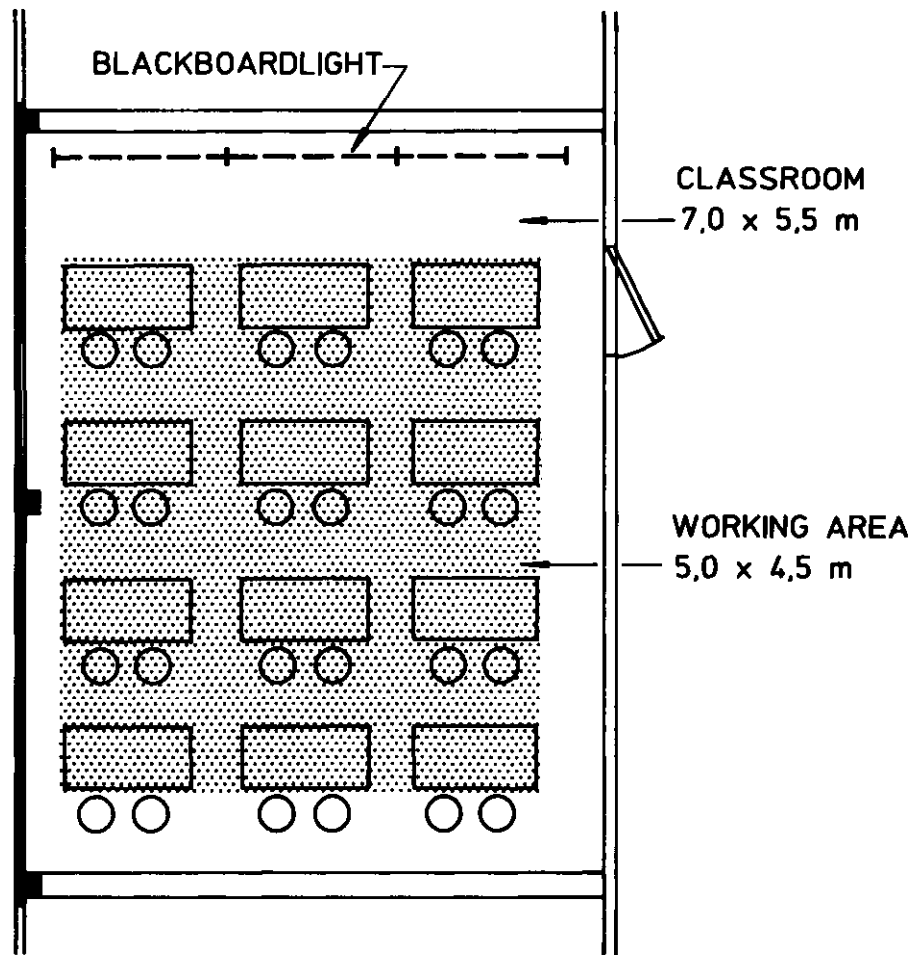
1000 hours/yr\*680 m<sup>2</sup>\*16.5 W/m<sup>2</sup>/1000 =

11,220 kWh/yr or 1,346.40 ECU/year

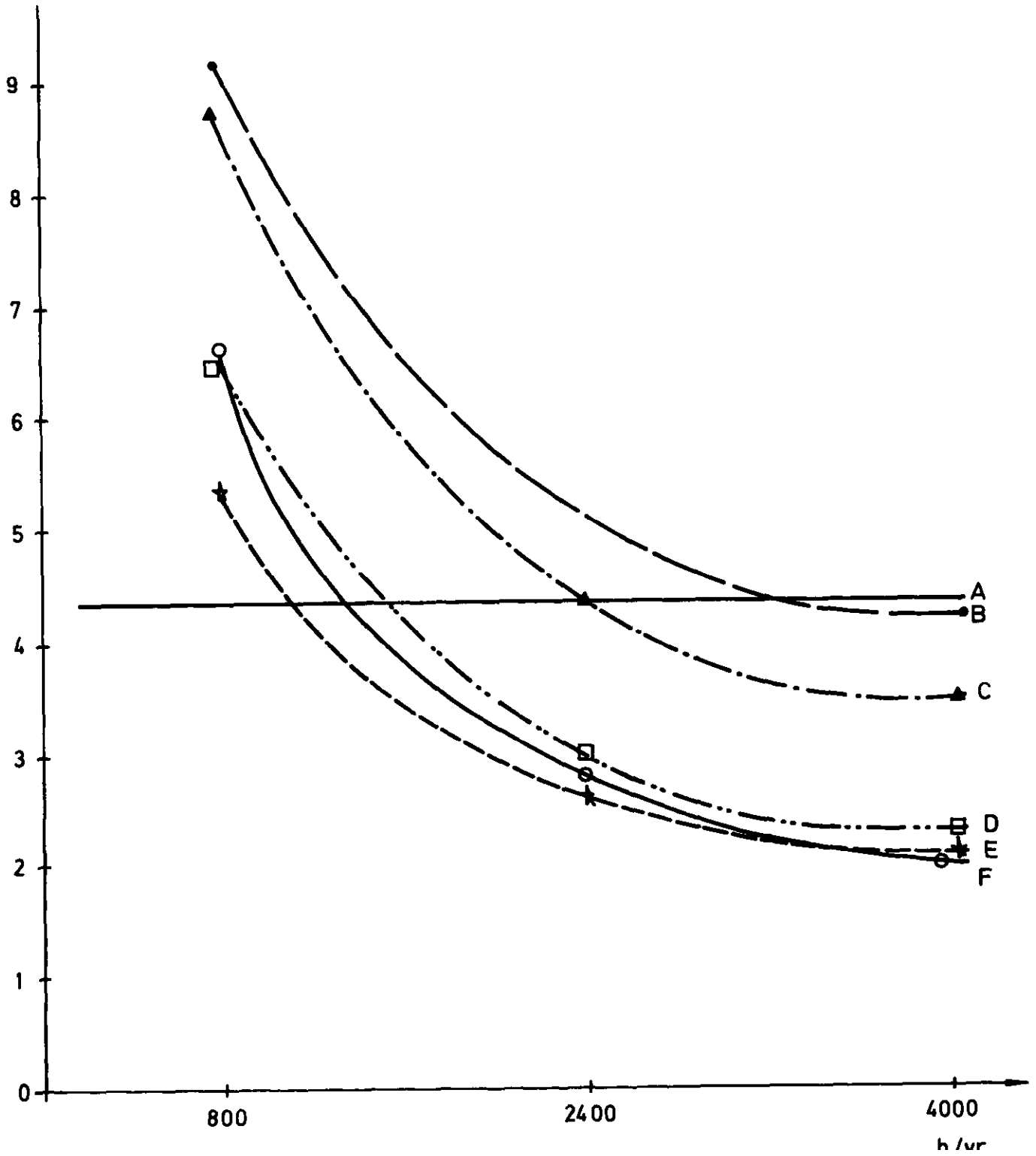
Column 14: The average general lighting level is measured to 105 lux instead of the 200 lux required in the Danish Guidelines. There are special light for the black-board.

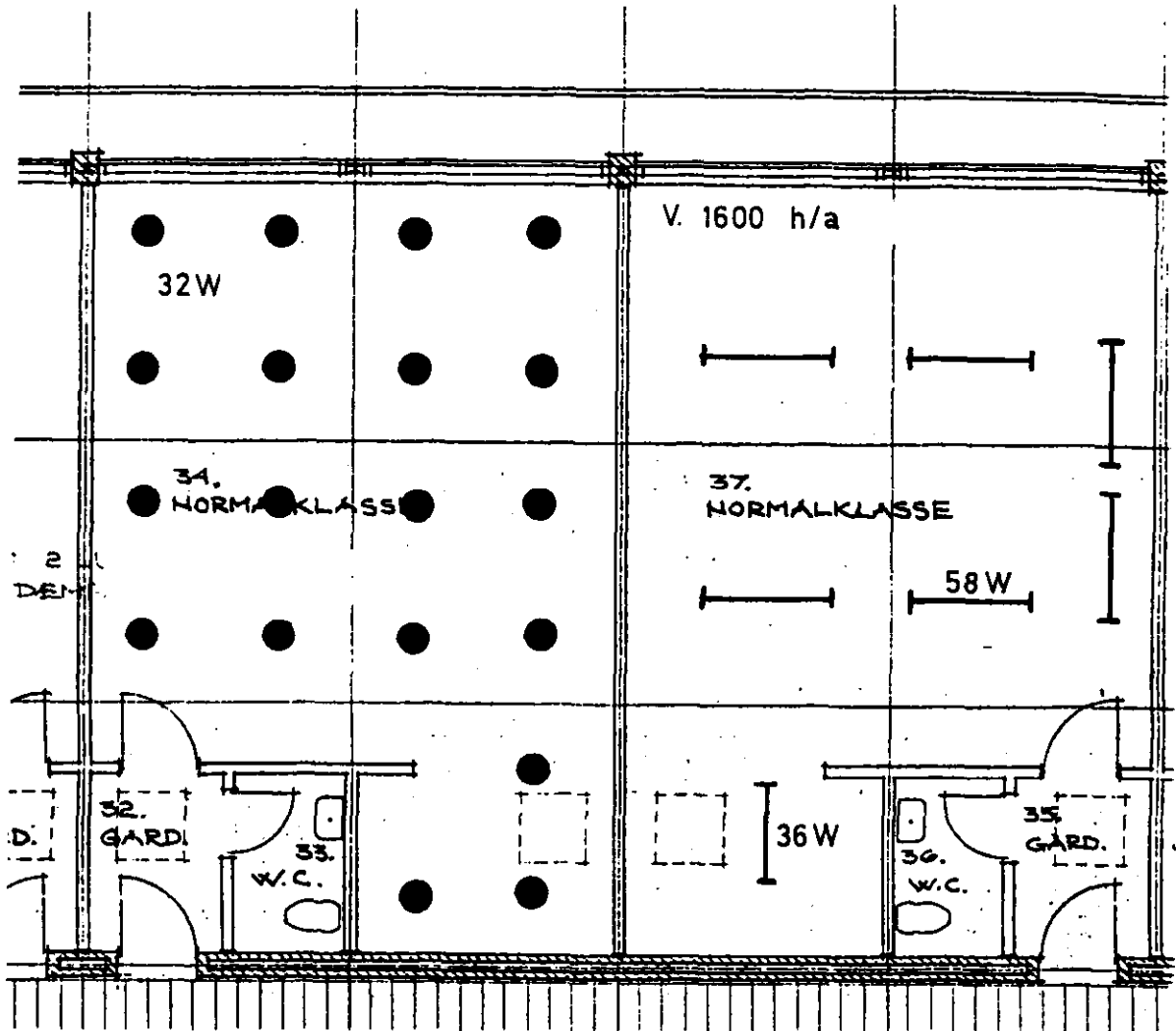
Fig. 3: The standardized energy audit form used to record energy consumption, potential savings and lighting level for 10 normal classrooms in a school.

# CLASSROOM



COSTS/CONSERVED ENERGY  
CENTS/KWH

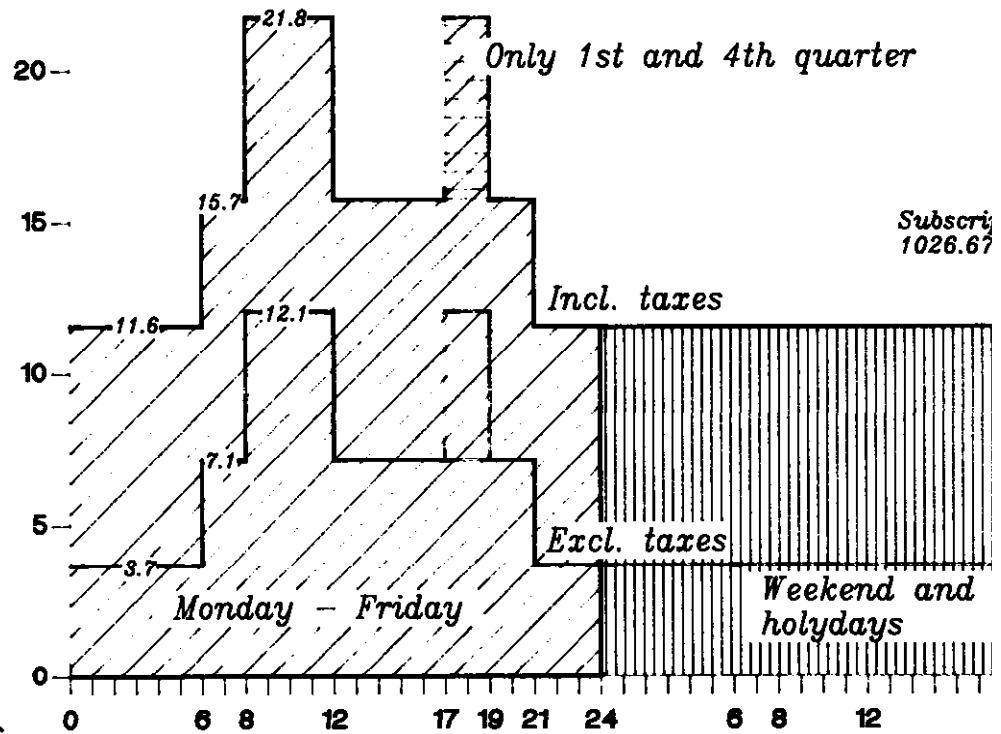




# TIME-OF-DAY TARIFF B

## Price Level 1 January 1991

Price  
cent/kWh  
25—



291

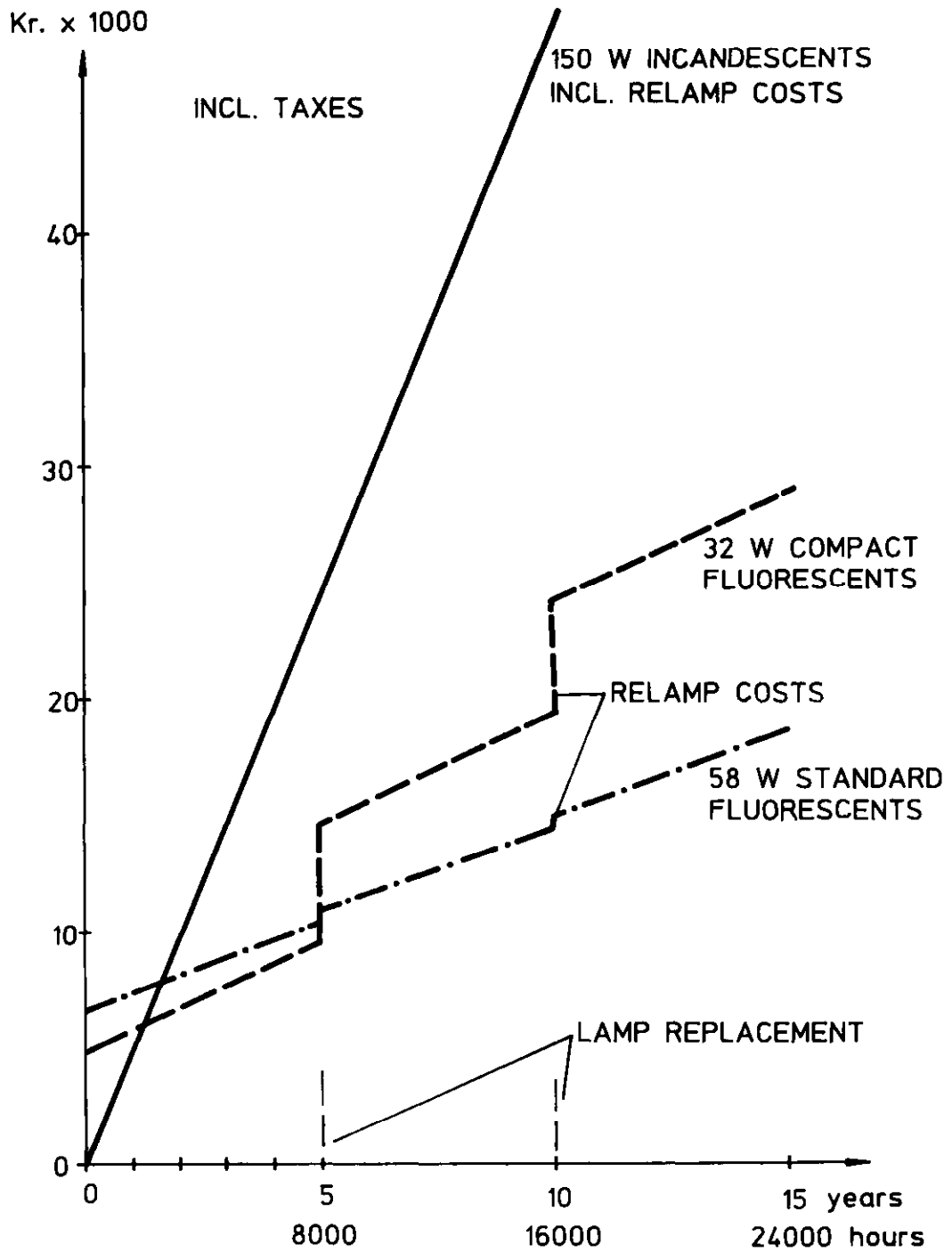


Technical Energy Consultancy

16.4.91

| Betegnelse/<br>Installationsnummer | Tidsrum for måling        |                     | Prisniveau:<br>Det d.d. gældende |             |             |
|------------------------------------|---------------------------|---------------------|----------------------------------|-------------|-------------|
|                                    | 14-17984                  | 09.03.91 - 22.03.91 |                                  |             |             |
|                                    | kWh                       |                     |                                  | %           |             |
|                                    | Årsbudgetforbrug          | Målt i 14 dage      | Opskalering til 1 år             | Afvigelser  |             |
| 1): 14-17984                       | 337.100 kWh               | 14.420 kWh          | 384.708 kWh                      | +14,1       |             |
|                                    | kr                        |                     |                                  |             |             |
|                                    |                           | Uden skatter        |                                  | Med skatter |             |
|                                    | Tarif                     | 14 dage             | 1 år                             | 14 dage     | 1 år        |
| 2): 14-17984                       | N                         | 6.489               | 173.124                          | 13.723      | 366.094     |
|                                    | B3                        | DKK 5.168           | DKK 134.534                      | DKK 12.111  | DKK 319.015 |
|                                    | Fordeling af energien (%) |                     |                                  |             |             |
|                                    |                           | Spidslast           | Højlast                          | Lavlast     |             |
| 3): 14-17984                       | B3                        | 17,5 %              | 26,1 %                           | 56,4 %      |             |

Fig. 4. THE TOTAL COSTS



AT 1600 h/yr  
 1000 DKK = 127 ECU.