NESA's Technical Energy Advisory Service
Methods Described by Means of Classroom Lighting Examples

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ABSTRACT

This paper describes the methods that are used by NESA's Technical Energy Advisory Service to obtain retrofittings of lighting installations that are good from a lighting engineering point of view and are profitable as to energy.

To be able to fix possible energy savings it is necessary to know the annual operating hours of the individual installations. If these operating hours are not known they have to be determined by means of measurements before the energy savings can be calculated.

Taking the operating hours into account proposals for new installations will be prepared. The energy savings that can be obtained when using good lamps, ballasts, fixtures, fixture locations and controls in a financially beneficial way will be incorporated in the proposal.

The individual initiatives will be given priority according to costs in proportion to saved energy. Only rarely is it possible to use all possibilities at the same time. It is necessary that the right solution is chosen according to the customer's need.

NESA is a Danish power supply company with about 500,000 customers.

Technical Energy Advisory Service is a new department guiding customers on rational energy utilization, including lighting.

The department advises customers having an annual consumption larger than appr. 100,000 kWh. Other departments look after the other customers.

When we advise customers we use low–energy ballasts and lamps, fixtures of a high conversion efficiency, located lighting and control systems. We prepare estimates of customer savings, and of the cost of making the savings.

It may be hard to calculate the working expenses as it requires knowledge of when a system is used. This aspect is due to the fact that our customers pay for their consumption to a time schedule having three different prices over the 24–hour period as shown in figure 1.

To establish the consumption pattern, the consumption is measured on the particular system currently over a fortnightly period. The consumption of the customer is then established in the particular price groups.

The annual consumption cannot be nailed down exactly but the picture of the consumer pattern will have to be so accurate that it may be used as an agreement basis, and also simple enough for the customer to recognize and accept it as his consumption.

Based on the consumption pattern and the tariff structures, an estimate of working expenses is made for the old and the new systems, as well as an estimate of the initial expenditure.

All project proposals observe, as minimum values, recommendations from Danish standards.

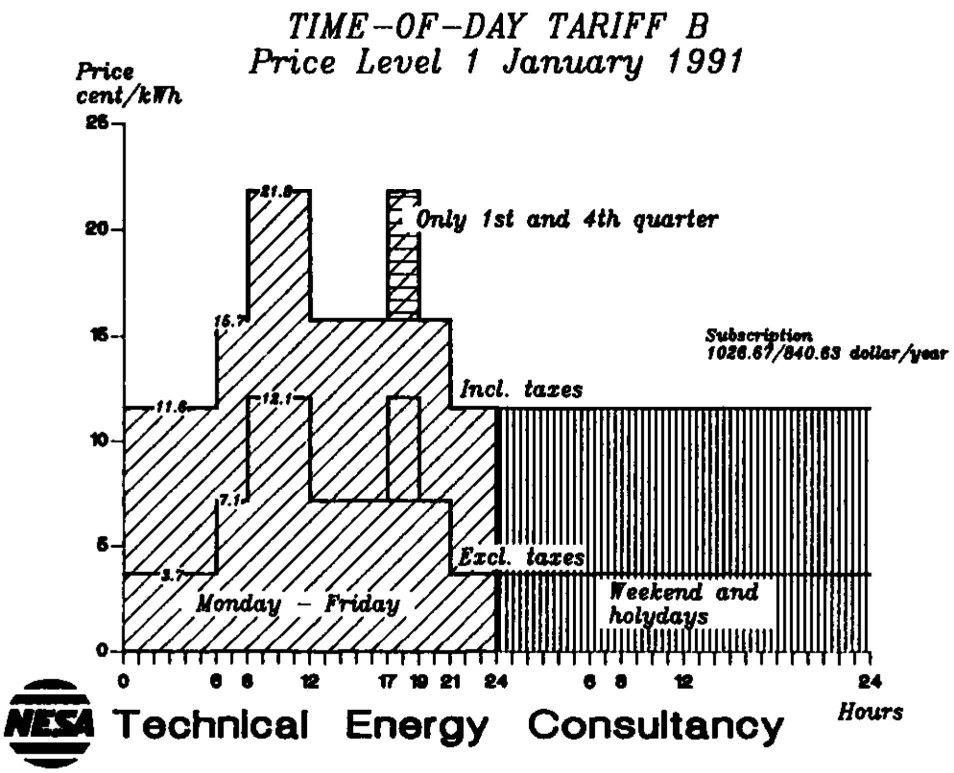

Figure 1. NESA's tariff for customers having an annual consumption of more than 100,000 kWh.

Beteg-nelse/ Instal-lations-nummer	Tidsrum for måling	Prisniveau: Det d.d. gældende
14-17984	09.03.91 - 22.03.91	

		kWh			%
		Årsbudget-forbrug	Målt i 14 dage	Opskalering til 1 år	Afvigel-se
1):	14-17984	337.100 kWh	14.420 kWh	384.708 kWh	+14,1

			kr			
			Uden skatter		Med skatter	
		Tafif	14 dage	1 år	14 dage	1 år
2):	14-17984	N	6.489	173.124	13.723	366.094
		B3	DKK 5.168	DK134.534	DKK12.111	DKK319.015

			Fordeling af energien (%)			
			Spids-last	Høj-last	Lav-last	
3):	14-17984	B3	17,5 %	26,1 %	56,4 %	

Figure 2. Tariff calculation. It shows a print from a computer program calculating tariffs from digital measurements.
Line 1): Consumption, previous year. Consumption, measured over a fortnightly period.Consumption, scaled up to one year. Difference between previous years and the measured consumption.
Line 2): Payment according to two different tariffs, without and with Danish taxes.
Line 3): Consumption in per cent, the three price groups.

A simplified example

At this school, there was in each classroom 19 fixtures, each having a 150 W incandescent light source. There was no blackboard lighting.

A proposal has been made to replace the incandescents by 32 W compact fluorescents.

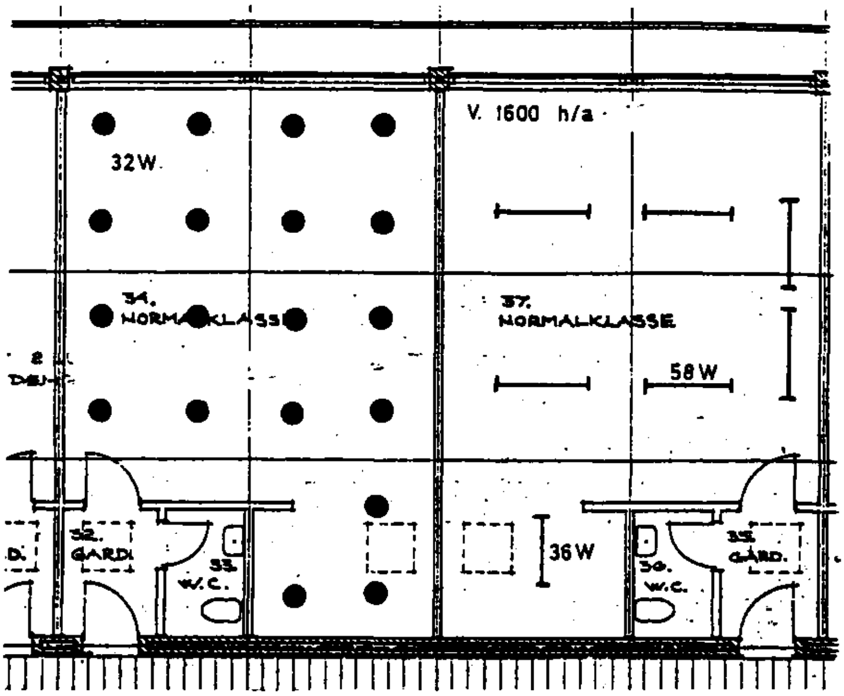

Figure 3. Marbæk primary school. Skibby, Denmark.

Our proposal was to dismantle all fixtures and instead install new fixtures for standard fluorescent lamps, partly as room lighting, partly as blackboard lighting. The room was used about 1,600 hours a year (incl. evening school).

The economic impacts are illustrated in figure 4.

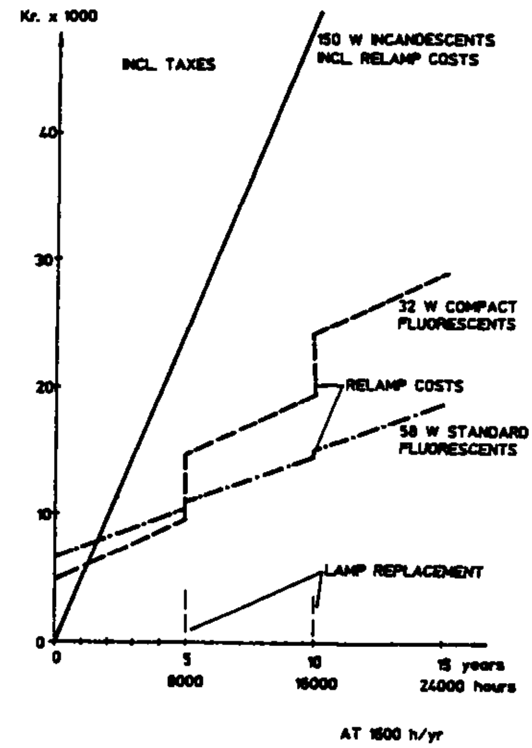

Figure 4. The total costs. DKK 1000 = ECU 127.

Figure 4 shows that the use of compact fluorescents entailed the shortest payback time. But considerations beyond the service life of the first set of lamps made the standard fluorescent lamps most advantageous. This solution was chosen.

When the old fixtures were taken down, the sockets and the cable ends were burned and the reflector box blackened. The two calculations with the existing fixtures ought to have added an amount for renovation of the existing fixtures. This is frequently the case.

Going over the methods

Lamp option

A frequently stated reason for the use of incandescents is that their initial cost is low.

Table 1. Comparison of various lamp options. USD 1 = ECU 0.724.

Lamps	Lumen	Lumen/$, excl. taxes	K Lumen h/$, excl. taxes
150 W incandescents	2220	1586	1586
100 W incandescents	1380	1568	1568
20 W PLC–E	1200	63	504
32 W Circolux	2000	99	792
24 W PL–L	1800	163	1304
36 W TLD–83	3450	645	5160
58 W TLD–83	5400	790	6320
50 W TLD–HF	5200	761	10500

Table 1 shows that incandescents are unrivaled in terms of the initial cost.

Evaluating the quantity of light in terms of life in relation to the initial cost, the classic fluorescent tubes would be preferable.

Table 2. System cost alternatives for a classroom (7.0 x 5.5 m).USD 1 = ECU 0.724.

Lamps	Prieces	Price fixtures $	Labor to install $	Excl.vat $	**Price/yr
150 W incandescents	16*	–	–	–	–
100 W incandescents	16	566	175	741	100
20 W PLC–E	16	566	175	741	100
32 W Circolux	16*	–	–	–	–
24 W PL–L	12	660	98	758	103
36 W TLD–83	6	570	98	668	90
58 W TLD–83	4	456	66	522	70
50 W TLD–HF	4	664	66	730	100

Table 3 Operating expense alternatives for the classroom. USD 1 = ECU 0.724.

Lamps	Lamps prieces excl.taxes, $	Labour costs excl. vat, $	Energi 0,0786 $/kWh	Working Expences excl. taxes, $
150 W	18	13	151	182
incandescents	54	38	453	545
	90	64	755	909
100 W	11	2	101	125
incandescents	34	5	302	374
	56	8	503	623
20 W PLC–E	30	2	20	52
	91	5	60	156
	152	8	101	261
32 W Circolux	32	1	32	66
	97	4	97	199
	161	6	161	330
24 W PL–L	13	1	23	37
	40	2	70	114
	66	3	113	185
36 W TLD–83	3	–	17	21
	10	1	51	63
	16	2	85	104
58 W TLD–83	3	–	18	21
	8	1	53	62
	14	1	88	104
50 W TLD–HF	2	–	14	16
	5	1	41	47
	8	1	68	77

In table 2 expenses for lamps are accounted for in the operating expenses. The existing 150 W fixtures are expected to be reused despite their poor efficiency. The 100 W incandescent example includes installation of 16 new efficient fixtures.

The same applies to the 20 W PLC–E lamps. In the 32 W Circolux example, the CFL lamps are installed directly in the old fixtures. With 24 W PL–L lamps, fixtures for two lamps have been used. In the 36 W, 58 W and 50 W HF examples, new suitable fixtures have been used. The examples show that the system price for new systems has been approximated to the same for the various lamps, except 58 W fluorescent tubes.

Table 3 shows that the operation cost of all types of fluorescent lamps is lower than that of incandescents though the lamp price is included in the calculation of the operating expenses.

In the example, the labour cost of current replacement of lamps has been fixed at USD 1 per lamp. This cost should be evaluated in each particular case as it may vary from many dollars right down to an insignificant expense.

For a closer evaluation of the expenses, the working expenses have been calculated for 800 hours, 2,400 hours and 4,000 hours per year (table 4).

In table 4 the column "conserved energy" shows the annual savings when changing the lighting in a classroom from 150 W incandescents to other lamps.

The costs per year include prices for energy, lamps, labour costs and writeoff of the new fittings.

The third column shows the proportions between the conserved energy and the costs.

Table 4. Energy savings and cost effectiveness for the classroom.
USD 1 = ECU 0.724.

	Conserved energy kWh	Costs/yr, excl. taxes $		Cost pr.conserved energy, excl. taxes $/kWh
150 W incandescents	–	182		–
	–	545		–
	–	909		–
100 W incandescents	640	225	*	0,35
	1920	474	*	0,25
	3200	723	*	0,23
20 W PLC–E	1164	152	*	0,091
	4992	256	*	0,051
	8360	361	*	0,043
32 W Circolux	1510	66		0,044
	4531	199		0,044
	7552	330		0,044
24 W PL–L	1632	140	*	0,086
	4896	217	*	0,044
	8160	288	*	0,035
36 W TLD–83	1704	111	*	0,065
	5112	153	*	0,030
	8520	194	*	0,023
58 W TLD–83	1696	91	*	0,053
	5088	132	*	0,026
	8480	174	*	0,021
50 W TLD–HF	1747	116	*	0,066
	5242	147	*	0,028
	8736	177	*	0,020

* Writeoff of the new fittings are included.

Figure 5 proportions these costs to the annual working hours.

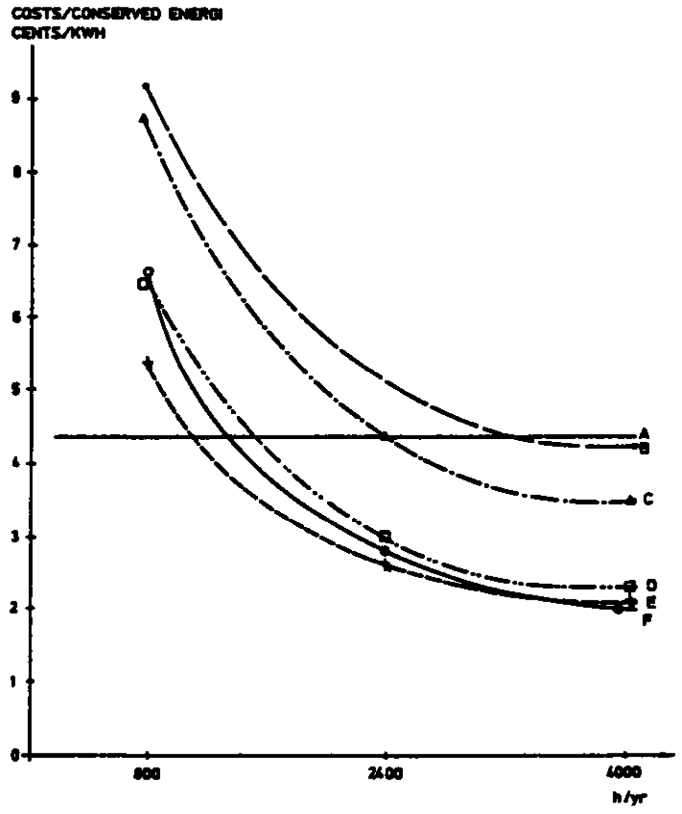

Figure 5. Cost effectiveness. Cost per conserved energy in relation tothe annual utilization.

Sign.:		
________	A	32 W Circolux
— — —	B	20 W PLC–E
—.—.—	C	24 W PL–L
—..—..	D	36 W TLD
- - - -	E	58 W TLD
________	F	50 W TLD–HF

It appears from table 4 and the graphs (figure 5) that utilization time below appr. 1000 hours per year suggests that replacement of incandescents with compact fluorescents yields the highest effect. With longer annual utilization, replacement of the system will be advantageous.

If other purposes require a light intensity of 400 lux or more, two–tube fittings can be used. It will improve the conditions, particularly for the solid–state high frequency ballast.

Low–energy magnetic core–coil ballasts are now available, but we do not have any experience of using them yet.

The example shows that the annual operating period of a lighting system is the most important factor when choosing the best profitable light source.

Fixtures

For energy efficient lighting it is imperative to choose the right fixtures, i.e. fixtures of a high conversion efficiency and fixtures that are easy to clean.

Furthermore the fixtures will, of course, have to meet lighting engineering requirements for the particular job.

Table 5. Fixture options for the classroom.

Fixture	Maintenance factor in %			Number of fixtures	Light intensity lux
	Lamps 58/83–TLD	Fixture	Result		
1*	0,85	0,95	0,80	4	215
2**	0,85	0,85	0,72	6	197
3***	0,85	0,70	0,60	8	202

Fixtures:

* Single parabolic easy–to–clean reflector, after one year.

** Dull white box with white lattice, lamps open with ballast, cables and sockets. One year. No cleaning.

*** Dull white box with white lattice, lamps open with ballast, cables and sockets, after 10 years. No cleaning.

Table 5 shows the numbers of different fixtures (1 x 58 W), when a light intensity of 200 lux is required.

In table 5 the same classroom has been used as previously. The same fluorescent tubes and illumination level requirement of 200 lux on the school desks have been used.

Using fixtures with single parabolic reflector which has been cleaned, the assignment may be handled using four 58 W fluorescent tubes.

With fittings of the type described as "white box with fluorescent tubes and all electric components visible", six 58 W fluorescent tubes will be required.

After some years, the box will be dirty and grey. On account of the visible installations, the box cannot be cleaned. The maintenance factor is easily reduced to 0.6. This means eight 58 W fluorescent lamps – or twice the energy consumption throughout the system life, if the demand for 200 lux shall be met.

In the example, the efficiency of the fixture is reduced by 17.5 %. Danish measurements show that it is not unusual that dirt reduces the efficiency of fixtures by 25 to 30 %.

Fittings with easy–to–clean reflectors with a high conversion efficiency constitute no novelty.

Unfortunately, the cost of the inefficient fixtures is lower in the two–tube version than good fixtures in the one–tube version. The price difference is frequently USD 25–50. The additional expense for good fixtures will be paid within the first 4,000 hours of life.

It is of utmost importance that you note the efficiency of the fixtures. The efficiencies of many technical fixtures are significantly reduced when other light sources are used than those for which the fixtures have been produced. This also applies when changing from incandescent to CFL lamps.

By using lighting fixtures with easy–to–clean reflectors it is possible to avoid systems with too many tubes during their whole life period and thus a lifelong overconsumption.

Located lighting

Located lighting indicates a system, where the light only has the intensity that is needed. In a classroom, 200 lux are required on the desks, 500 lux on the blackboard and 50 to 70 lux in the gangways.

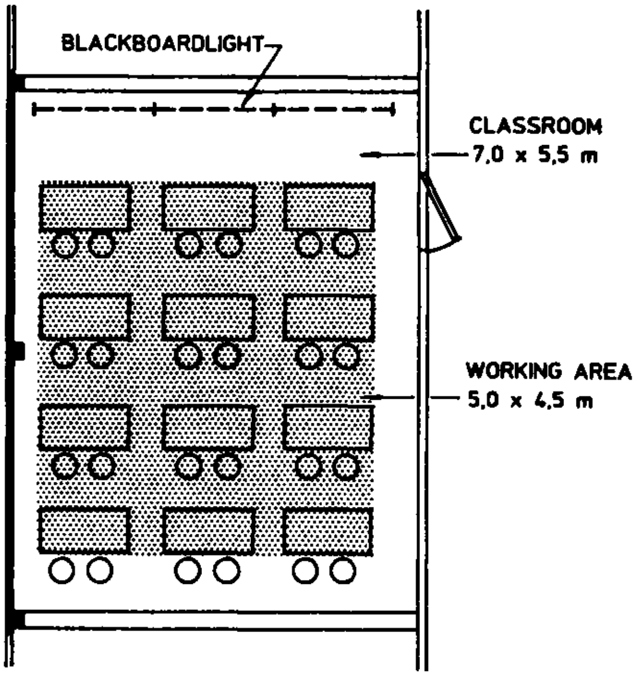

Figure 6. A classroom. The working area is dotted.

If the entire room is illuminated at 200 lux, four 58 W fluorescent tubes will be required. If the requirement of 200 lux is maintained only for the desk area, the job may be handled by using four 36 W fluorescent lamps.
Table 6. Located lighting used on the desk area in a classroom.

	Fixture	Numbers fixture	Load	Light intensity
Classroom 7,0 m x 5,5 m	1 x 58 W	4	0,28 kW	211 lux
Working area 5,0 m x 4,5 m	1 x 36 W	4	0,18 kW	206 lux

Light intensity demand: 200 lux.
Fixture: single parabolic reflector.
Lamp: Philips TLD 58/83 or TLD 36/83.
Total, maintenance factor: 0.80.

In table 6 the same type of fixture has been used in 36 W and 58 W version. If 200 lux is required in the whole classroom, the load is 0.28 kW. If 200 lux are only needed on the desk area, 0.18 kW will be enough.

If located lighting is used with care, it is possible to achieve fascinating, modulated lighting systems, lower system prices and lower working expenses. The price you pay for this is some flexibility with regard to furniture arrangements. To some extent, this can be counteracted by means of suspension systems, where the lighting fixtures can be moved according to requirements.

Control systems

The most immediate energy savings may be generated by turning off lights burning unnecessarily, but generally lights are not turned off when people leave their offices, and "Turn off the light" campaigns have only a short-term effect.

Automatic turn–off systems controlled by occupancy sensors or (more simply) for instance by school ringing systems may save much energy. Also, systems dimming or turning off the light with increased daylight could reduce the energy consumption. Solid state HF–ballasts may dim the light infinitely, varying from full light to turn–off. The additional price per fixture will, in relation to magnetic core–coil ballasts, be ECU 55 to 65 (excl. VAT).

Potential energy savings will depend on virtually anything but the light system, e.g.:
- Size and form of rooms and windows
- Colours of rooms and window frames and the immediate environments
- Direction towards the sun and its sky height
- Other buildings and trees
- Time of using the building.

Energy savings of 70 % have been documented in an office building in the centre of Copenhagen by using a HF dimming system (8 Vognmagergade, DK–1149 Copenhagen K).

Conclusion

A great deal of energy can be saved merely by replacing incandescents by CFL lamps. However, it will often be advantageous to the energy consumption as well as to the total costs if a renovation of the system is carried out at the same time using the best suitable light sources, ballasts and fixtures.

As we, in our project proposals, always link energy savings with the total costs of achieving the savings, we still have not tried to project systems to decidedly the smallest energy consumption.

In our many projects that have been completed we have reduced the energy consumption by many MWh, and at the same time we have had contented customers. They know in advance for how long they are going to pay for a small energy consumption and pay instalments on costs with an amount not exceeding the expenses for the energy consumption, if they had not renovated their systems.

If the simple payback period for a renovation is less than five years, NESA can offer its customers a favourable financing arrangement.

Until the autumn of 1991 NESA's Technical Energy Advisory Service has analysed 166 buildings with an annual consumption of 110 GWh. We have pointed out savings of 12.3 GWh. 63 of these projects have been carried out. The annual consumption was 25 GWh. By means of measurements we have documented savings of 6.3 GWh per year. The total cost was DKK 19,200,000 (ECU 2,400,000).