Strategies for Technologies Procurement in Creating Energy-Efficient Lighting Installations

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ABSTRACT

Although the energy-saving potential of reducing electric lighting energy use in offices and residential environments is large, the use of energy efficient systems has been limited, particularly in residential applications. Examples of the barriers to more efficient lighting systems use are the lack of knowledge and how the lighting decision making channel is built. This paper examines Dutch market trends for office and consumer lighting. It describes the trends, strategies and impediments to office and residential lighting savings.

INTRODUCTION

Due to the variable use of artificial lighting it is worthwhile to determine which lighting systems are used for visual tasks and which for ambiance tasks. If you also determine the changes in current and future uses, you can then conclude which possibilities are available to reduce energy with, in principle, no lack of comfort.

First, the current sectors where artificial light is most often used are: offices, residences, stores and malls, industry, healthcare, social care, public lighting, hotels and catering, education, sport and recreation, agriculture and greenhouse horticulture. Table 1 gives an overview of the lighting hours in these sectors. Table 2 shows which lamp type is commonly used in the particular sector.

From table 2, we can develop an energy conservation strategy based on lamp type. However this is only one factor which determines the lighting energy. In addition to lamp type, the energy factor is dependent on:

1. assembly, such as lamp, ballast, connection facility, switch or drive capability.
2. functions such as the right lamp for the right place: inside, outside, safety lighting.
3. application possibilities: luminaire contruction for mounting in or on the ceiling; railsystems; free standing luminaires on the floor or table; light generators with optical light transmissions; special applications such as underwater lighting, greenhouse lighting, medical therapy.
4. shape, design which determines the luminaire efficacy, light distribution, glare, ultraviolet/infrared radiation.
5. control possibililities such as time switching, activity dependent control, personal control, daylight control, combinations.

This report will be limited to the trends and future expectations for offices and residentials due to the fact that these two sectors use the most energy for lighting.

OFFICE LIGHTING

At present, most offices in the Netherlands have similar lay-outs with the same possibilities for furniture arrangement, technical installations and general lighting. Changes are underway due to more effective use of the space, higher efficiency of the business operation and increased productivity. Also the end user needs are changing due to reduced difference between the home environment, free time and the work place.

Due to an increased need for changes, the office infrastructure needs ease replacement of the lay-out. The trend in the pattern size (repetitive distance between two fixtures) is decreasing from 1.8 meter to 1.2 m. For the lighting industry this means different lamp and luminaire size, more requests for indirect, direct and workplace oriented lighting.

For a well designed office befitting the needs of the user,

Table 1. Lighting energy per sector

Sector	Yearly operating hours a)	Yearly energy use in GWh b)	Yearly energy in % of the total energy	Yearly energy used by fluorescent lights in GWh, c)	Yearly energy other light sources in GWh
Offices	2200/400	5100	6.8	3400	1700
day/night					
Residences		3750	5	750	3000
inside	125 - 1300				
outside	300 - 3000				
Stores/Malls		3600	4.8	1500	2100
day/night	2700/200				
Industry	2200/200	1575	2.1	3100	-
day/night					
Healthcare		1125	1.5	750	375
day/night					
not bed related	2200/500				
bed related	4000/1000				
Social care		750	1	500	250
day/night	2200/400				
Public lighting	4000	750	1	-	-
Hotels		600	0.8	150	450
day/night	2200/400				
Education		525	0.7	350	175
day/night	1600/400				
Sport		225	0.3	150	75
day/night	2000/1000				

'-' number is not known.
Acriculture and greenhouse horticulture are unknown.
a) Source: (NOVEM Dat licht zo, 1994)
b) Source: (Overheidsstrategieën voor energie-efficiënte binnenverlichting in Nederland, 1995) indexed for 1995 based on the total electricity in the Netherlands of 75.000 GWh per year exclusive the powerloss in the distribution system.
c) For the industry the numbers do not match due to different sources.

it is increasingly important that specifiers, contractors, installers, facility managers, architects, designers and suppliers speak each other's language. These people also form the decision making channel for the effective use of energy efficient lighting. Another component of the lighting decision channel is the government by its regulation, laws and as one of the largest facility managers.

CURRENT OFFICES

Most Dutch offices are built as follows: an entrance hall including a counter and seating area; a couple of offices of 3.6 x 5.4 m and/or larger spaces (but multiples of 1.8 m), meeting spaces and a cafeteria. The variety in individual office space is limited to space for 1 to 3 persons, group spaces for 12 people and an office layout for many cubicles. The ceiling is characterized by 1.8 m patterns with built-in general direct lighting luminaires. Switches are by the door, with occasional computer controlled switch system.

Changes in office tools such as computer screens, key boards, telephones, faxes and printers have increased the need for luminance reduction. These facts have lead to a change from general direct lighting to indirect lighting with pendles and special workplace luminaires. A side effect is that end users like these type of luminare designs and the improved perception of the space.

An example of currently used lighting systems with installed power, investment and operation cost are shown below. The office hereby is defined as a space of 3.6 (w) * 5.4 (d) * 2.7 (h) m with two permanent desks. On the desk the standard maintained light level is 400 lux. For situation c), the general light level is 150 - 200 lux and locally supplemented to 400 lux. The prices are list prices (excluding tax) which can be lower in larger projects. The number of burning hours is set on 2200 per year during the day. The lifetime of fluorescent light is set on 12.500 hours including the electronic ballast. The kWh-price is $0.10, the lamp removal cost is based on 0.15 hours times $25.00 = $3.75 per lamp. The disposal cost is $1.00 per lamp.

Table 2: Lamp type per sector *)

Sector	GLS-lamps	Halogen Lamps	Fluorescent lamps	Compact Fluorescent lamps	Other Gas Discharge lamps
Offices	O	O	OOO	OO	O
Residences	OOO	OO	O	O	O
Stores/Malls	O	OO	OO	OO	OO
Industry	O	O	OOO	O	OOO
Healthcare	O	O	OOO	O	O
Social care	O	O	OOO	O	O
Public lighting	O	O	O	O	OOO
Hotels/ catering	OO	OO	OO	OO	OO
Education	O	O	OOO	O	O
Sport	O	O	OOO	O	OO

*)O = not or almost not used in this sector
OO = often used in this sector
OOO = almost always used in this sector
Source: BEK reports, based on interviews

Table 3. Lighting cost (in $) in terms of energy and maintenance

Lighting system		a *)	b *)	c *)
Investment cost		650	700	1000
Subsidy 1996 d)		55	40	20
Investment / m^2 include subsidy		31	34	50
Energy cost	general lighting	2.52	3.98	1.70
/ m^2 / year	desk lighting	-	-	0.45
Maintenance cost	lamps	0.22	1.05	0.45
/ m^2 / year *)	lamp removal	0.15	0.27	0.35
	lamp disposal	0.05	0.10	0.10
	igniters	-	-	-
Total energy and maintenance cost per m^2 per year		3.45	5.35	3.05

*) currency: $1.00 = fl. 2.00
a: general, ***direct lighting*** with built-in/on ceiling mounted luminaires with a standard fluorescent lamp.
b: general, ***indirect lighting*** via a reflector with built-in/on ceiling mounted luminaires
c: ***limited*** general lighting, ***indirect lighting*** with pendant luminaires accomplished with local desk lighting.
d: government subsidy to stimulate energy reduction

System a)
Most used in the Netherlands with a fluorescent lamp of 1 * 58 W, aluminium reflector and louvers for glare reduction. The installed power is 11.5 W/m2 with electronic ballast.

With a daylight control system the energy reduction can be 25% or up to 40% depending on the window surface, glass type, location of the building. Other reductions are possible with more efficient luminaires which are improved with super reflectant material of 95%.

System b)
As an alternative for system a), the lamp is not visible from any direction. From research done by (Bodmann, 1992), these luminaires are appreciated by the end-user. The diffuse light reflected by a white reflector gives low glare levels on monitors. The style is also appreciated by many people.

System c)
To reduce energy through reduction of the general light level, pendant luminaires are used, installed with a lower lamp power. If compact fluorescent are used for the desk lighting, the installed power can be limited to 9.5 W/m2. Due to a selective use, the energy will be lower compared to the general lighting system a).

Alternatives for the above lighting systems:
• general light with reduction of the luminaires for local places where less light is needed, for example by the door.

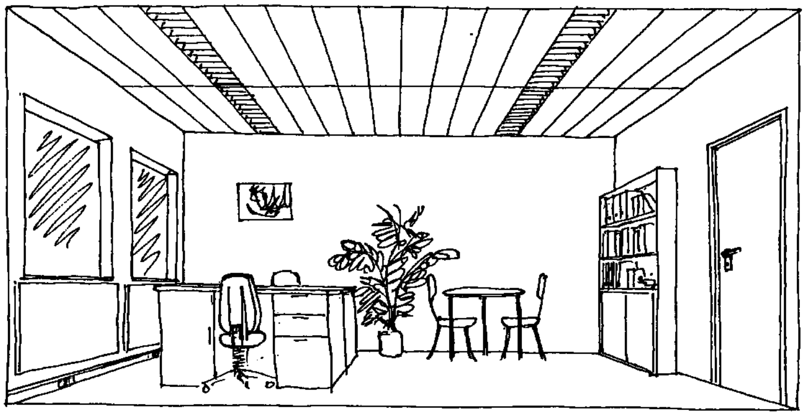

Figure 1. System a).

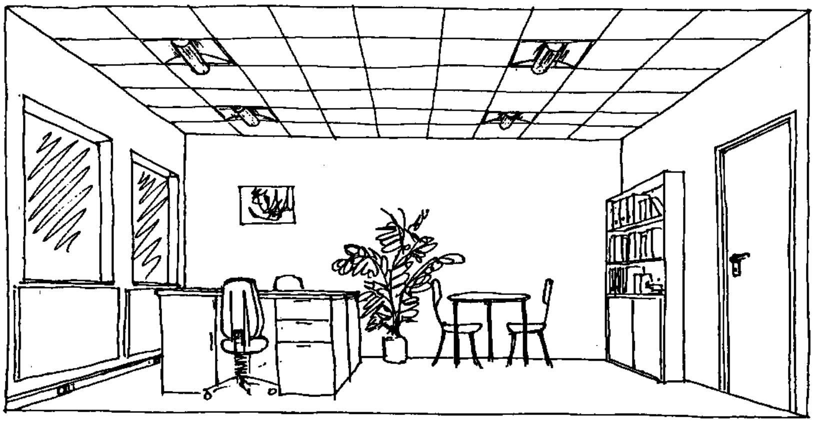

Figure 2: system b)

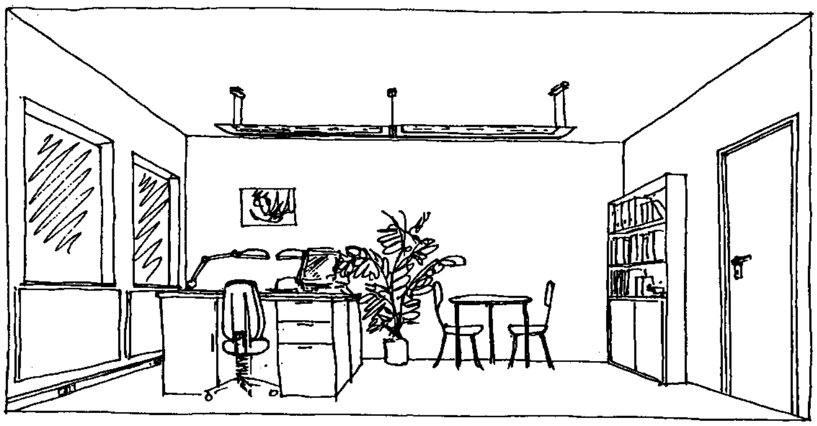

Figure 3: system c)

• local direct light with CFL (compact fluorescent lamp) in combination with local desk light or local uplighters.
• higher efficacy luminaires with an improved reflector design around the smaller T5 fluorescent lamp.

IMPEDIMENTS, TRENDS AND STRATEGY

It is acknowledged that the use of daylight can reduce the electrical lighting. However, the use of daylighting control systems has been limited. Why? First, cost remains a major barrier. Second, specifiers and installers lack the knowledge in advanced lighting equipment and how to get the optimal performance from the technology (Buddenberg and Wolsey, 1995). Third, manufacturers' data is very limited in regards to maximizing performance (Buddenberg, 1995). Fourth, development of the electronic components is lacking when compared with other advanced office equipment such as computer systems which have built in sleep modes. Currently, the *trend in daylight control is individual control* per luminaire.

In small businesses, the office is not used 70% (Visser, 1995) of the time due to meetings at other locations, work at home or on the road, illness, vacations, etc. There has been little success in experiments designed to change the organisational structure and office lay-out for a more efficient use of the space, desk and energy.

Ideas about defined working hours and remote work locations will probably change in the next few years to better fit the employee's needs in dealing with child care, free time activities and traffic problems. The office space will be better suited to the individual's need with a more emotional, home-like, playful character. The office will be changed into a place where one can work, listen to music, watch television and meet people who are not related to work.

Facility managers are talking about office concepts such as cloister and cocoon offices. This last term means a space for c*ommunication* and *concentration*. Further we see shared desk/office, walk in office, action office, social office, hotel office (per hour per room, paid for with your pincode). Dutch office furniture manufacturers are already playing with these concepts. The users are classified as residents, nomads, guests. And the organization determines the office type in terms of administration office, trade office, counter/service office and innovation office.

In many cases the new concepts are *reducing the foot print size* (the area that each occupant is using) of the office. The well-being of the user becomes more important, improved by a healthy climate, good lighting and an ergonomic work space. The lighting function is to produce a good impression and to help increasing the performance of a task.

As a result the office pattern size is changing from 1.8 m to 1.2 m, the installed power will increase due to the anticipated larger amount of luminaires to be installed. The luminaire investment cost (Buddenberg, Visser 1997) will increase from $20 - $40 for 1.8 m pattern to $30 - $60 for 1.2 m pattern per square meter.

Dutch subsidy for energy efficiency in 1997 changed from stimulating the electronic ballast to daylight and occupancy control. Since 1997, the Netherlands has had the energy investment tax reduction law which allows companies to substract energy saving light installations from their taxable profit. Also, there is an energy efficient program to stimulate energy savings in government buildings (Korbee, 1995).

Possible strategies for the Netherlands are:

- conducting research on lighting systems to be used in new office concepts. What are the energetic consequences, which designs need to be improved?
- define an energy efficient criterium for lighting, which stimulates the use of energy efficient lighting.
- stimulate, through use of interactive CD-ROM, internet WEB sides, etc, the information which needs to be available at every level in the decision making channel.
- develop a lighting information center, which provides information dedicated to energy efficient lighting.
- stimulate the research of energy efficient luminaires including daylight and occupancy sensors.

RESIDENTIAL LIGHTING

Table 1 shows that, in the Netherlands, residential lighting is the second highest in lighting energy. An average houshold uses 500 kWh per year in lighting which is 18% of the total energy use of that household. Without government promotion for energy savings the average lighting energy per household will grow to 520 kWh per year by 2000 (Kemna, etc. 1991), due to increasing number of lights and outdoor lighting.

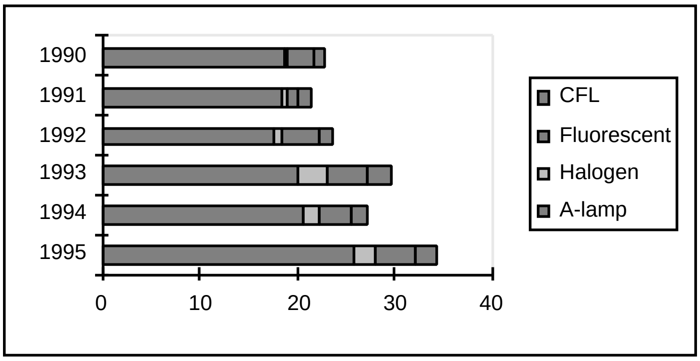

Figure 4. average lamp numbers per household between 1990 - 1995 The difference in 1993 and 1994 is due to a different set of questions, (Source: BEK, 1988-1995)

The potential reduction in the consumer sector is determined by the residential lighting market and building trends. The decision making channel here is composed of the project developer, housing cooperative, contractors, architects, interior designers, lighting designers, installers, manuafacturers, wholesale and retail chain outlets and finally, the consumer himself or herself.

Overall in the *decision making channel* energy conservation is not an issue in the choice of a light fixture. For example, houses are not designed for increased use of fluorescent lights. CFL's are there as a replacement for the A-lamp (GLS lamp), but fixtures designed around a CFL are not often found in the home depot.

In general, an architect's, installer's or interior designer's decision is based on a known fixture.

Manufacturers and wholesalers are very conservative in making choices for more energy efficient fixtures. As a result, the introduction of a new lamp takes 10 - 15 years. Which explains why new developments in the lighting market will never happen without pressure from outside the industry. As illustration, in the Netherlands, 50% of the available fixtures are purchased by a small group of wholesalers (less than 15). Their product knowledge and vision is crucial for lamp types found in the stores.

Another reason for the conservative market is the *consumers' knowledge*. An active demanding market is built by knowledgeable players. The consumer knows the incandescent lamp: maintenance is easy, the price is low and a short lifetime does not play a role. Other lamp types have higher prices and are in general more difficult to replace. More knowledge is needed about using other lamps instead of the A-lamp for a particular task and the right ambiance. Due to poorer color rendering than that of incandescent lamps, the consumer also has a negative feeling about fluorescent light and has not often used other lamps.

Price drives the purchase of the fixture. The Dutch consumer buys 70% of his lamps at the supermarket, depart-

Table 4. lamp type per space in an average Dutch household in 1995 (Source: BEK, 1988-1995)

Lamp type	Total	A-lamp a)	Halogen lamp b)	Fluorescent lamp c)	CFL d)
Living room	7.86	5.84	0.97	0.24	0.81
Kitchen	3.25	1.65	0.29	1.18	0.13
Hall, Toilet, Landing	3.30	3.00	0.07	0.06	0.17
Sleeping room	7.07	6.08	0.35	0.44	0.20
Bathroom	1.63	1.29	0.16	0.12	0.06
Attic, garage, shed	3.13	1.77	0.03	1.26	0.08
Outdoor lighting	1.67	1.06	0.1	0.05	0.46
Total	27.91	20.69	1.97	3.35	1.91
Reserve lamps	6.09	5.13	0.20	0.39	0.37
Total incl. Reserve	34.00	25.82	2.17	3.74	2.28

a) general lighting with A-lamp in ceiling luminaires, table lights, pendant luminiare, etc.
b) halogen lighting as global lighting with uplighter, down lighter, desk and furniture light, etc.
c) in luminiares for fluorescent lights used in coves and furniture
d) compact fluorescent lamps in luminaires and furniture.

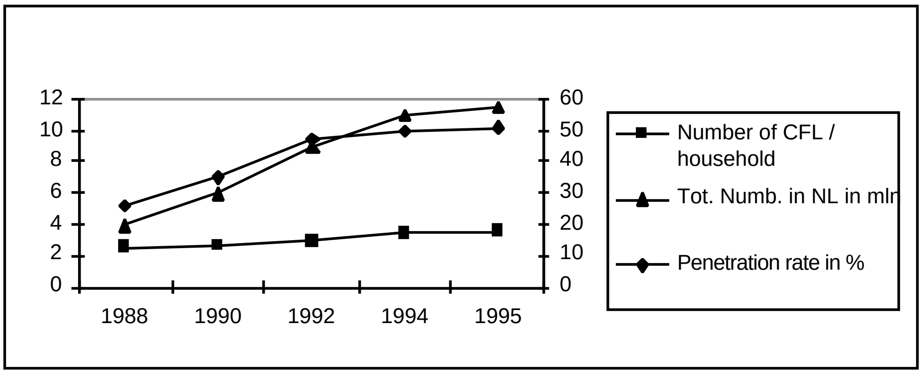

Figure 5. Number of CFLs in a Dutch house

ment store or do-it-yourself chain (Van Holstein en Kemna 1991). The retailers' knowledge is very limited however, when advising the consumer about applications of lamps and luminaires. Attemps to increase the retailer's knowledge are not successful due to the fact that typically only one person is taught and he or she does not share the knowledge with other workers in the store.

CURRENT RESIDENCES

Currently residences are characterised by a living room connected to an open kitchen; hallway with bathroom and stairwell; two or three sleeping rooms and a bathroom. Sometimes an attic, cellar, garage and shed, balcony or garden with terrace are found. The total amount of lamps per household increasing by roughly 10 lamps over the last 5 years.

Of the 34 lamps, roughly seven are used in the living room. In 1988 these seven lamps were distributed as six standard incandescent lamps: the A-lamps and one CFL. Five years later, the average in the living room is still roughly seven lamps, but now is distributed as six A-lamps, one CFL and one halogen lamp. It is interesting to note that not all lamps are burning at the same moment. Respondents in the research group have an average 4.4 lamps switched on at one time. Over the period from 1988 - 1995, the number of burning lamps is nearly constant. However, the lamp type changes: in '88 almost only A-lamps were burning; in '95, the A-lamps decreased to 3.5 with a 0.5 CFL and a 0.4 halogen appearing.

The characteristic home mentioned earlier has, in 1995, roughly 34 lamps. Table 4 shows the distribution of space and lamp type. "Reserve" lamps are lamps which are available but in general not switched on.

If you count the CFLs and linear fluorescents together, the number of incandescent lamps is still a factor 5 higher then the energy saving types. Another trend noted is the number of lamps which are used in luminaires. Particularly in spot light types, the number of lamps has grown from one to two or three per fixture. More halogens are also used in this type of spot lighting. Together with the demographic trend of increasing number of one person households, the total lighting energy demand is still growing.

The market development of CFLs is shown in Figure 5. Over the years the number of CFL per household does not change much (left Y-axes), however the total number of households with CFLs is growing due to the increased penetration rate: 25% in 1988 to 50% in 1995.

The application for CFL is particularly concentrated in the living room, 48% of all CFLs used, compared to 18% used in an outdoor luminaire, 7% in the kitchen, 8% in the sleepingrooms and 19% in hall, toilet, bathroom, attic, garage, etc.

The limited CFL use is partly explained by the few available fixtures which are designed for a CFL. The shape, size, weight, lower color rendering and the fact that most CFL types are not dimmable, all these factors do not inspire the fixture designer to design a challenging energy saving luminaire.

The use of switching devices is limited in the 1995 Dutch household. Dimmers are on an average of 0.8 units per house. In addition, they are not always used according the BEK researchers (BEK, 1988-1995). Dimmed fluorescent are almost never in use due to no choice in the ballast type built in the luminiare. There are an average of 0.7 time switches per house. Only a small percentage of these timers are used daily. Light sensor switches average 0.3 per house, most often used in outdoor applications together with an occupancy sensor.

CONSUMER BEHAVIOR

The current consumer plays more with light than 10 years ago, which has increased the number of connected fixtures. In figure 5 the amount of CFL's per house seems limited to 2 or 3 units. In general, the *consumer's decision* to purchase is based on cheap price or a beautiful design. Lamps are purchased at important moments: buying the first house, moving to another house and when the kids move out. Halogen uplighters are used more often due to their flexibility in location, ability to dim and the high light level which makes this luminaire practical for working /reading light during the day and atmospheric light during the night. The consumer, however, still considers the A-lamp the best mix of price, size, atmosphere, light color and ease of maintenance.

IMPEDIMENTS, TRENDS AND STRATEGIES

The development of a *consumer dedicated CFL luminaire market* is lacking compared to the office CFL fixture market. The marketing of CFL's, however, has grown to the point that they are located on the shelf next to the incandescent lamps in the supermarket. New fixture designs in popular trendsetting furniture stores are based on incandescent lights, however.

Improved communication between the professional and consumer market will help to get professional components, such as dimming ballasts, also introduced to the consumer market.

Energy savings can come from *new technology* combined with a well introduced campaign. Previously it took 10 - 15 years before new lamps were used by the average consumer when technologies were introduced without a stimulus program. Currently, if you look to the penetration rate, stimulus programs have a positive influence on the acceptance of a lamp in the marketplace. However, the program needs to be a continuous process, a one-time price reduction on CFL's will not stimulate the next lamp purchase.

Current government stimulus rules for energy efficient lighting are not effective enough. The goal was four CFL per house. The trend has stabilized to an average of 2 to 3 per house over the years. Figure 5 demonstrates that while the number per household remains constant, the penetration rate has increased.

There is still a role for the government in terms of *stimulus programs and laws* to implement better technologies. Without these programs, the energy demand will increase, due in part to the increasing number of fixtures per house and to more indirect light from halogen lamps with high power.

New programs can be developed to stimulate purchase and use of CFL's. An example is to increase the need for and the availability of dimming CFL fixtures, particularly for applications with long burning hours. Design lamp application regulations or recommendations which apply for specific applications such as a kitchen fan, kitchen/living room furniture, etc., with fluorescent light, (dimming) electronic ballast and good color rendering. Require energy efficient labels on fixtures with efficient ratings of the lamp, fixture and the ballast.

C*onsumer knowledge* is still at the level of using A-lamps and candles. To improve consumer knowledge, dedicated lighting education through use of flyers, exhibitions, roadshows and retailers could be offered by utility companies, government and schools. Other examples: *green* interiors designed by furniture stores, green displays by lighting stores, home depots and department stores. All this can be connected to the *fun shopping* trend. In *advertising campaigns* text such as "You would be a fool to use incandescent lamps in your yard" could be used.

A-lamps are not covered under the *waste disposal programs* as fluorescent lights are. This gives the idea of an environment friendly lamp, which it is not when compared to CFL's. A more energy efficient solution to halogen uplighters are switchable CFL uplighters. To get these in the living room, though, special efforts in design need to be done.

Occupancy applications are not limited to offices. Their use in the house is not marketed as a handy alternative for the regular switch however. In particular, handicapped and older people enjoy the comfort of an occupancy sensor.

CONCLUSION

One of the largest barrier in the technology procurement of energy-efficient lighting installations is the decision making channel for office lighting and the consumer market.

The office pattern size is changing from 1.8 meter to 1.2 meter which has impact on the number of fixtures in the office. Future office uses can be improved by a classification rating system in relation to flexibility, health, energy consumption, maintenance and visual tasks.

This study shows the current office lighting trend to use nearly all indirect fixtures. Further development of electronic components will reduce energy use and will give more control to the individual user which will fit the changing needs of the office user and owner types.

This paper should provide insight to energy savings potential for residential lighting, particularly in the evening and night hours and only with the lights used in the living room, kitchen and sleeping rooms. This study showed that the consumer has a greater interest in light than only 10-15 years ago which will increase the number of fixtures. However the consumers' lighting knowledge is still on the practical level of A-lamps and candles.

Further, energy saving is based more on trends, fashion, thoughts and preferences. Consumer education will work only if available in a continuous form. New energy savings technologies with insentive programs will increase the penetration rate faster than normal market forces. ●

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