DELight

Energy and Environment Programme
Environmental Change Unit
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Domestic Efficient Lighting

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The main findings and conclusions are provided in this Final Report. Additional research is described in the Supporting Material. Both publications are available from each of the partners, or direct from the ECU (address on back cover).

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EXECUTIVE SUMMARY

By 2020, 43% of residential lighting electricity consumption in the EU could be saved through identifiable policy actions. This report demonstrates how such savings could be achieved.

Electric lighting is used in practically all households throughout Europe and represents a key component of peak electricity demand in many countries. There is already a well developed energy-efficient technology available on the market, in the form of compact fluorescent light bulbs (CFLs), that could deliver substantial savings. Such savings could be accessed quickly due to the rapid turnover of light bulbs in the stock - the challenge is to get the more efficient technology installed and guarantee the savings. No other changes in consumer behaviour are necessary. The agreement (still to be ratified) reached during the Climate Change Convention at Kyoto in December 1997 was for targets to reduce CO_2 emissions to be 'legally binding'. This requires greater confidence and certainty that any potential savings will be achieved. Lighting represents an area of potentially large, rapid and guaranteed energy savings that could usefully contribute to these challenging international objectives.

The DELight project incorporates data on domestic lighting from all over Europe, focusing on the EU, with in-depth analysis of three countries: Germany, Sweden and the UK. These three countries account for 40% of households and almost half of all domestic electricity consumed in the EU. Spain was also included in one part of the detailed studies to represent countries in Southern Europe. This is the first time such detailed information on residential lighting in Europe has been brought together. Previously data were sparse and coverage is still inadequate, but evidence in this study demonstrates that domestic lighting is of greater importance than present policies have recognised, both in magnitude and energy savings potential.

The particular focus of this study has been to combine information on both the bulb and the light fixture. Research on the potential energy savings from changing the bulb alone results in optimistic and inaccurate estimates: the aesthetics of lighting are crucially important and the existing fixtures in homes are a major constraint that has to be recognised.

THE LIGHTING PICTURE

- Total domestic lighting consumption in the 15 EU Member States is at least 86 TWh (17% of all residential electricity use) and expected to rise to 102 TWh by 2020, largely because of the growth in household numbers.

- At the national level, average household lighting consumption ranges from 240 kWh pa to 920 kWh pa across Europe. However, the majority of these figures are simple estimates and without more reliable figures, the true importance of this sector can not be confirmed.

- Detailed modelling of lighting consumption for Germany and the UK reveals electricity use to be far higher than previously thought - at least double prior estimates in both countries.

- Lighting electricity use is dependent on a number of factors, such as size of house (m^2), number of inhabitants and income. The relative importance of each has not been established.

- The average number of light bulbs is 24 per house across the EU. The majority (at least 70%) are incandescents, with the remainder being fluorescents (strip or CFLs) and halogens. In Germany and Sweden, there are more halogens than CFLs in the stock.

- The light source manufacturing industry is dominated by three multi-national companies, common to both the residential and commercial sectors, whereas light fixtures are manufactured by over 1000 companies in the EU, often specific to the residential sector. Far Eastern imports are increasing in both markets.

- Successful collaboration between these two disparate industries has been demonstrated by the rapid development of the market for halogen bulbs, which require specific fixtures.

- The lighting retail market is split, with most consumers habitually purchasing bulbs in supermarkets, where fixtures are not available. Most fixtures are bought in specialist lighting shops or DIY stores.

- One new fixture is bought by the average household annually, as either a replacement or an additional item.

- Fixtures can be viewed as personal possessions and taken when moving house or may be treated as part of the building fabric, varying from country to country.

- Expenditure on lighting in the EU is 10.3 bn ecu on electricity, with a further 5 bn on fixtures in 1995. The value of the bulbs is not included.

- There is growing interest in the use of lighting in the home, illustrated by the popularity of torchiere uplighters (using high wattage halogens) and an expected trend towards increasing numbers of fixtures. Without intervention, this is likely to increase lighting electricity use, but also represents an opportunity for the installation of more energy-efficient lighting.

OPPORTUNITIES FOR SAVINGS

Compact fluorescent light bulbs (CFLs) use at least 60% less electricity than the traditional incandescents while lasting ten to twelve times as long and can therefore deliver substantial savings in terms of both electricity and money. Their long life means they need replacing less often and so are particularly suitable for use in inaccessible fixtures or for elderly or disabled people. Integral ballast CFLs, with a screw or bayonet base, currently represent the best opportunity to achieve significant electricity savings in residential lighting since they are the most energy-efficient technology suitable for use in fixtures already in the home. Pin-based CFLs are also available. These have a separate ballast either in a screw or bayonet based adapter (modular system) or incorporated into the fixture (dedicated system).

Ownership of CFLs is still relatively low, with consumer ignorance and confusion preventing wider use. Many of the problems associated with the use of these bulbs in the existing fixtures could be avoided through the use of fixtures designed for pin-based CFLs. Dedicated fixtures optimise the light distribution and performance of CFLs and improve the cost-effectiveness of installation (pin-based CFLs are cheaper than the integral ballast versions), as well as guaranteeing the savings and future bulb market. While dedicated fixtures are common in the commercial sector, there is a lack of suitably designed fixtures for the residential sector, representing an energy-saving opportunity that has not yet been fully exploited.

- Only 30% of households in the EU currently have at least one CFL, with those households that own them having an average of three or four.

- Three to four CFLs per owning household appears to be a stage in the development of residential lighting - a higher level of ownership is possible. People who are happy with their existing CFLs are unlikely to switch back to incandescent bulbs in these fixtures.

- Across Europe, the main advantages of CFLs are seen as environmental or lower running costs.
- The Spanish purchase CFLs predominantly for their bright light, which is particularly valued in Southern Europe.
- Ownership of CFLs is highest in those countries with the lowest price of CFLs relative to GLS (general lighting service) bulbs. These tend to be the countries where there have been a number of high profile CFL campaigns, such as Denmark and the Netherlands.
- Experience of CFLs, through using them in the home, doubles the proportion of people who view them positively.
- Two-thirds of CFL owners consider that CFLs provide a suitable light for all activities. A similar proportion believe that CFLs do not fit in all their fixtures. The constraint for these households is seen as the fixture, not the bulb.
- When a wide range of CFLs were demonstrated in the home by a lighting expert, the householder agreed that at least 40% of their fixtures, without alteration, were suitable for CFLs. This is an average of eight bulbs. There was almost complete agreement between the professional and the householder on what was deemed ‘acceptable’.
- Wall and ceiling fixtures were more suitable for use with CFLs than table or floor-standing luminaires.
- Replacing the four most highly-used bulbs, in fixtures identified as suitable, would save around 200 kWh, worth 24 ecu pa per household in electricity savings. This represents over a quarter of the electricity consumed by domestic lighting in Germany, Sweden and the UK.

BARRIERS TO BE OVERCOME

- The main reasons for not owning CFLs were that they were too expensive or the householder had never considered purchasing one. Ignorance and uncertainty were more important reasons for non-ownership than dislike of the bulb or the quality of light. Even current owners of CFLs need assistance in recognising the opportunities for installing CFLs in their fixtures.
- Consumers lack confidence in the durability and continuity of CFL technology. The range of CFLs on the market is confusing and they do not know how to choose the appropriate one for their fixtures. There are limited opportunities for trying out CFLs at present.
- The present retail structure for bulbs and fixtures and the lack of informed retail staff is preventing the education of the public on how to use CFLs correctly in the fixtures in the home.
- There is little collaboration between the bulb and fixture manufacturers in developing a range of well-designed fixtures suitable for CFL use in the residential sector, so the annual purchase of a new fixture is likely to add to the stock of inappropriate fixtures.

THE WAY FORWARD

It has taken a considerable number of promotions and rebate schemes to get the first 135 million CFLs into European homes, partly because of their high price. Increasing ownership further will need a continuing level of policy support. However, if the full savings available in this sector are to be realised, a coherent strategy is required to transform the lighting market. Market transformation is a well established strategic approach, utilising a combination of policies, such as education, labels, rebates, procurement and standards, to speed up the introduction of energy efficient technologies into the home. This approach is currently less well developed with domestic lighting than with appliances.

The market for dedicated fixtures needs to be developed now, through collaboration between the manufacturers, to ensure the availability of a sufficient range of suitable fixtures within the next five years. In parallel with this, promotion of integral ballast CFLs needs to be continued in the short term because of the current lack of dedicated fixtures. The underlying aim of any approach must be to build a positive image of CFLs to lay the foundation for the successful transfer to dedicated fixtures.

- The initial objective is to get a CFL into every home, so that households can experience this type of light and establish where and how they would like to use it.
- The ultimate aim of any market transformation strategy for lighting must be for the majority of fixtures in the home to be dedicated to more energy efficient light sources.
- The constraint in the short term will be manufacturing capacity and consumer confidence. In the longer-term, it is essential to transform the fixture market.

RECOMMENDATIONS FOR BUILDING A POSITIVE IMAGE

- Attractive, well-designed dedicated fixtures could be developed through procurement or competitions to widen consumer choice.
- Free or heavily subsidised CFLs is the most effective way of getting the first of these bulbs into the 70% of homes currently without one, this should be accompanied by an explanatory leaflet.
- The quality of CFL products on the market needs to be guaranteed, with continuity and compatibility of technologies. The Energy Label provides a good basis for this, possibly in combination with a ‘quality list’ of CFLs as used in Denmark and Sweden.
- People should have the opportunity to try out CFLs, either through test samples or with a guaranteed refund.
- Appropriate mechanisms need to be put in place for the safe disposal of fluorescent bulbs to prevent pollution from mercury and phosphors.
- Transforming the fixture retail sector would enable consumers to obtain clear information and advice on the appropriate use of CFLs. An accreditation scheme would identify shops with trained staff.
- A ‘suitability label’ on fixtures would enable consumers to identify the appropriate CFL to use.
- Retail outlets could use CFLs in the existing fixture displays, demonstrating their correct application and raising awareness among both retailers and consumers.
- An EU Corporate Average Bulb Efficiency standard (CABE) is one possibility: a negotiated agreement requiring a certain efficiency of the average bulb sold, with improvements each year. This would combine flexibility with guaranteed savings and support the long-term strategy.

The switch from incandescents to CFLs is as revolutionary as the switch from gas to electricity in domestic lighting 70 years ago and needs to be recognised as such. The role of suitable fixtures is of similar importance.

CHAPTER 1: INTRODUCTION

This report presents the main findings from the DELight project, an investigation into the realistic level of savings available in domestic lighting, given the constraints of the market, the technologies and the aesthetics of lighting. Full details on the work undertaken can be found in the Supporting Material (available on request from the ECU).

Domestic lighting is an area which has been poorly studied across the whole of Europe. The lack of information in this area is surprising considering how ubiquitous electric lighting is throughout European households.

Lighting is a complex area. Not only is it a necessity to be able to see by, but lighting also has strong cultural significance. It plays an important role in decorating the home and creating an atmosphere - lighting has been described as the 'jewellery of architecture'. Such factors will determine the type of light people have in their homes and the way in which they use it, as well as the energy savings accessible in this sector.

For most countries, only rough estimates for the amount of electricity consumed by the lights in people's homes are available. Before this study was undertaken, there were no estimates for domestic lighting consumption across the whole of the EU. In the UK, prior to the DECADE study, figures quoted for domestic lighting consumption were found to underestimate actual consumption by almost 50% (Palmer 1997, DECADE 1995). Without a reliable base line, it is impossible to identify the magnitude of savings that could be made in this sector and to evaluate what savings might already have been made. Only through a better understanding of domestic lighting will it be possible to identify the policies, both at the national and European Union (EU) level, that will secure reductions in energy use.

Lighting is an area where electricity savings could be made relatively quickly and cheaply. Light bulbs are a frequent purchase and a technology that could enable such savings to be made is already on the market in the form of compact fluorescent light bulbs (CFLs). That is not to say that this is the only technology that is worth pursuing, but this is the best currently available.

Why are savings needed? The discussions at the Climate Change Convention at Kyoto in December 1997 resulted in the agreement that the targets set should be 'legally binding', which means essentially that national governments have to guarantee these savings. Such targets centre around the need to reduce the level of CO_2 emissions. The extent to which this is an important issue for any one country depends on the electricity generating mix of that particular country. However, electricity savings may still be important for other reasons, such as the phasing out of the nuclear power stations, as is the case in Sweden. Lighting is also a key component of peak demand in many countries, which may also be a strong motive for reducing demand in this sector.

0.1 LIGHTING POLICIES

Much progress has been made at the European level for energy-saving policies on domestic appliances since the introduction of the Framework Directive 92/75/EEC on energy labelling, in 1992. The domestic appliance market has adjusted to such legislation, accepting further legislation on efficiency standards for cold appliances (refrigerators, fridge-freezers and freezers) and voluntary agreements for both the wet (washing machines and tumble dryers) and brown (TVs and VCRs) markets. However, policies affecting the domestic lighting market have not be so forthcoming. The lighting industry is complex, being a combination of two technologies, the bulbs and the fixture, which have two quite different market structures.

The only two policies currently in place for domestic lighting at the European level apply to light sources. These are an Energy Label on light bulbs due to come into force in the year 1999 (although not mandatory until 2001) and a negotiated directive on energy-efficiency classes for fluorescent bulb-ballast systems, providing the basis for removal of inefficient systems from the market. Other programmes at the European level include the International Energy Agency (IEA) procurement programme on a replacement incandescent light bulb (RIL), also known as the ‘future bulb’, which would lie somewhere between a standard incandescent bulb and a CFL in terms of energy efficiency.

At a national level, most policies have, again, focused on bulbs rather than fixtures. Almost all European countries have undertaken some type of lighting campaign, often run by the utilities. The key motivation for utilities to become involved with such programmes is to reduce peak demand, since domestic lighting often represents a key component of peak load. However, it is not clear how involvement in these programmes will be affected by the liberalisation of the electricity supply industries across Europe. Experience gained through past policies can inform future policy, as discussed in Chapter 9.

0.2 WHY THIS STUDY?

Given the lack of information available on domestic lighting, there was an obvious need for a start to be made in this area, particularly given the important role this sector has in achieving the emissions targets agreed at Kyoto.

The original key aims of this project were to undertake:

- Market analysis (both historical and projected) for national and EU market transformation policies for domestic lighting, including luminaires and lamps,
- A more detailed analysis of the market, technology, behaviour and barriers to increased efficiency for three countries in particular, and
- To establish the criteria for an EU Appliance network (this is covered in a separate publication).

Previous studies on lighting have focused on light bulbs, without considering the role of the fixture. Since it is the interaction between the light source and the fixture which results in the quality and distribution of light provided by the luminaire, it is important to consider these two technologies together rather than as separate entities. The aesthetics of lighting are another important consideration if energy-efficient lighting is to be successful. DELight has focused more on the role played by the fixture, both those already installed in the home and the need for fixtures which are specific to energy efficient light sources, providing a realistic assessment of the potential for savings in this area. Most of the research has centred around CFLs and obstacles to their installation, since this is currently the energy-efficient technology most suitable for the residential sector. However, much of the discussion is relevant to the problems that need to be tackled for any replacement for the traditional incandescent bulb.

CHAPTER 2: TECHNOLOGIES

Electric lighting did not become common in European homes until around the 1930s, although the first carbon filament light bulb was patented by Edison in 1879. When first introduced, electric lighting was promoted for its health advantages over gas, being a clean, safe alternative. However, it was considered to be harsh and less ‘kind’ than previous light sources and some homes were apparently reluctant to lose the heat benefit from the gas flame (Rudge 1997). Light source manufacturers produced booklets to advise people on how to use this new technology, with guidelines on where to use lights for specific tasks. Electric light was considered a luxury, incandescent bulbs being an expensive commodity. In the UK, the lighting electricity tariff was also higher than that charged for other electricity uses.

From when it first appeared on the residential market, the incandescent GLS (general lighting service) bulb was recommended for its comfort and colour attributes and has remained the dominant technology ever since. Efficacy of this technology has improved over the past 60 years, from 3 lumens/Watt to an average of 12 lumens/Watt today (Starby 1992, Davis *et al* 1993), but over 90% of the electricity used by an incandescent bulb is still lost as heat. The Edison screw base was standardised in the USA when the production process was first mechanised at the end of the nineteenth century and this type is found in most countries today. However, the bayonet cap has remained in use in UK households since it was introduced by the Edison and Swan company in 1884 (Rudge 1997). With further advances in the manufacturing processes, the GLS bulb is now the cheapest light source available, in contrast to the early high prices. Manufacturers have concentrated on extending the range of different types on offer, with a wide variety of wattages, colours and sizes currently available. Tungsten halogen bulbs first appeared on the market in 1959 and represent an improvement in incandescent technology with better efficacy and quality of light, as well as longer bulb life.

Fluorescent strip lighting was introduced into European households in the 1940s, but the ‘cooler’ light produced by these bulbs has meant that its application has been limited, being used mainly in kitchens. Compared to incandescent bulbs, there have been huge advances made in fluorescent technologies, with improvements in the quality of light as well as continual increases in efficiency and decreases in tube size - both diameter and length. A further development of this technology resulted in the production of compact fluorescent lights (CFLs) in the early 1980s - these are essentially folded fluorescent tubes.

In terms of the history of light fixtures, the early electric bulbs were used in the existing light fixtures that had been installed as oil or gas lamps. However, manufacturers recommended the use of specially designed fixtures for a more satisfactory result. Many early fixture designs imitated the traditional light forms such as candles or gas lamps and bulbs in the shape of a candle flame are still popular today. As incandescent bulbs were improved and became brighter, it became desirable to shade the bulbs rather than leaving them bare. Indirect lighting and the use of a variety of light points to avoid monotony was recommended as early as 1926 (Rudge 1997). In UK households, there is normally a single central light point in the middle of the ceiling and the possibilities for extra lighting are limited by the number of electric sockets available.

The advent of electric lighting in homes has altered the way in which people use space and time. They are no longer restricted by limited light sources or the hours of daylight, leading to substantial changes in the way in which people lead their lives (Garnert 1993). The use of incandescent bulbs in the majority of households throughout Europe provides both the light source and light fixture manufacturers with a guaranteed market. Demand from consumers for an incandescent replacement is low. Hence, there is little incentive as yet for the lighting industry to take up new ideas and developments (Rudge 1997).

1.1 LIGHT SOURCES

The basic light sources available on the European residential market do not vary widely between countries. A brief overview is given here to highlight some of the issues relevant to changing to more energy-efficient lighting, providing the context for the later discussions. There may be slight differences in terms of wattage and colour of bulbs sold in each country, but the characteristics of each type of light source are essentially the same. These light sources can be classified into five general categories, as summarised in Table 2-1. It is not appropriate here to give an exhaustive list covering the full range of different bulbs within in each category; the table is intended to provide a broad comparison between the different types and hence uses average figures. Much of the following technical information has been obtained from the E Source Lighting Technology Atlas (Audin *et al* 1994) and the lighting catalogues of Philips and Osram. More detail is provided in Chapter 3 of the Supporting Material.

Table 1-1 Basic properties of the key domestic light sources

Light source	Bulb wattage [W]	Efficacy [lm/W]	Length [mm]	CRI	CCT [K]	Average life [h]	Ballast required	Dimmable
Incandescent								
GLS	15-150	6-18	90-120	95+	2800	750-1500	No	Yes
Low voltage halogen	15-65	8-20	40-60	95+	3000	2000-4000	No Requires transformer	Yes
High voltage halogen	75-500	13-29	85-115	95+	3000	2000	No	Yes
Fluorescent								
Fluorescent strips	4-58	65-100	150-1500 Ø 7-40	51-95	2800-6500	10 000-20 000	Yes	Some
CFL	5-36	42-82	85-215 Ø 12.5-17.5	82-85	2700 - 4000	10 000 - 12 000	Yes	Some

Notes *(technical definitions appear in the glossary):*
GLS - General Lighting Service
Efficacy - a measure of the light provided (measured in lumens, lm) per unit of input power (Watts). The higher this is, the more efficient the light source.
Ø - fluorescent tube diameter
CRI (Colour Rendering Index) - this has a maximum value of 100. The higher the CRI, the 'better' the colour of illuminated objects appear.
CCT (Correlated Colour Temperature) - the higher the CT, the 'cooler' the light appears.
Average life - number of hours after which, on average, 50% of bulbs will have failed

1.1.1 Incandescent light sources

GLS incandescent bulbs are the most commonly used light source in the residential sector - people are familiar with the technology, the bulbs are cheap and easy to use, have good colour rendering properties and can be dimmed. The majority of European households use screw-based GLS bulbs, with bayonet-based bulbs confined to the public and commercial sectors. However, in British and Irish households, bayonet-based bulbs are common. GLS bulbs are the least efficient light source with low efficacy and short operating life. Their life span can be extended by operating at reduced voltage, although this results in lower efficacy. Conversely, using a higher voltage will reduce the average life of the bulb: operating a 240V incandescent at 250V can reduce average life expectancy by 57% (Starby 1992). GLS bulbs emit light of approximately uniform intensity in all directions.

Halogen bulbs represent an improvement on GLS bulbs - the technology is essentially the same but with the filament enclosed in halogen gases. This extends the life of the filament and improves both efficacy and light output although long periods of dimming will reduce bulb life. Halogen infrared-reflecting (HIR) bulbs have an even higher efficacy due to a special coating within the bulb that reflects infrared radiation back onto the filament, resulting in a higher filament temperature. Screw and bayonet based halogens are available, but the majority are pin-based and so require specially designed fixtures. Low-voltage halogens operate at 12Vor 24V and therefore require a transformer, either magnetic or electronic, which uses additional power - around 10 to 20% of the bulb wattage. Operating at low-voltage has the advantage of allowing the use of smaller filaments, giving smaller bulbs with tighter beam control. The use of reflectors in these bulbs produce a focused beam of light in one direction. This type of halogen is often used for display and accent lighting and is popular in the commercial sector. High-voltage halogens are non-directional light sources commonly used in halogen torchieres - these are inexpensive uplighters, typically using 300-500W halogen bulbs, providing a bright, indirect and diffuse light.

A further development in incandescent technology is being encouraged through the International Energy Agency (IEA) technology procurement competition for a replacement incandescent bulb - the ‘future bulb’. The specification requires a bulb which is 30% more efficient than current incandescents and lasts around three times as long (Davidson and Borg 1997). It is unlikely that the winning bulb will be available on the market before 2001, since the call for bids has recently been reissued (Davidson 1997).

1.1.2 Fluorescent light sources

The two main classes of fluorescent light sources used in the residential sector are strip lights and CFLs. These are both based on the same technology (CFLs being essentially a folded fluorescent tube) which is different and more complex compared to incandescent bulbs and is also more efficient. Fluorescent light sources require a ballast to function, the type of ballast used (magnetic, electronic or a hybrid) being a primary determinant of bulb efficacy. Increased efficacy is also associated with longer length and smaller diameter tubes. They give a linear diffuse light emitted from the entire surface of the tube, unlike the point source of an incandescent filament. The type of phosphor used to coat the walls of the tube determines light quality. Advances in phosphor technology have led to improvements in fluorescent light quality over the years, with a wide range of bulbs of different Colour Rendering Indexes (CRI) available today. Fluorescent lights last around ten times as long as incandescent bulbs, although those operated by magnetic ballasts are more sensitive to switching than those with electronic ballasts - their lifetime is dependent on the number of times they are started and the length of time they are then used. Average lifetime figures are usually quoted on the basis of three hour cycles per start (three hours on, twenty minutes off). Switching cycles of less than three hours will result in decreased lifetime due to erosion of the cathode. Recent tests have found high quality electronically ballasted products to be unaffected by frequent switching (Pedersen 1997, Stiftung Warentest 1995).

CFLs are smaller and more compact than full sized strip lights, due to folding of the tube, which is also narrower and shorter. The narrow diameter makes it economical to use high-quality phosphors, which give good colour rendering and high efficacy. The patent on the particular phosphor used in CFLs has recently expired, which may result in improvements in the light quality of cheaper bulbs. CFLs are generally of lower efficacy than strip lights, since the folds in the tube shade the light output in places, but they still represent around a four fold improvement on incandescent efficacy (Table 2-1).

There are three main classes of CFLs: integral units, modular units and dedicated systems. Dedicated systems are the only type to include the fixture. Integral units are those where the ballast and CFL are incorporated into a single assembly. These are intended for use in fixtures designed to take standard incandescent bulbs and so have a screw or bayonet base. Modular and dedicated systems use pin based CFLs, with two or four pins, which plug into a separate ballast (modular) or directly into a fixture incorporating the ballast, either in the actual fixture or in the plug (dedicated). Integral units are dominant in the residential sector at present. The CFL bulbs used in any of these systems are available in a wide range of shapes and sizes, the main types being two, three or four finger (with the tubes sometimes folded), 2-D and circline. The major manufacturers, such as Philips and Osram, are starting to produce CFLs enclosed within a glass envelope, giving it an appearance similar to that of a traditional incandescent bulb. These bulbs have a lower light output and a shorter life (around 5-6000 hours) than standard CFLs (Borg 1997).

CFL efficacy varies widely with wattage, phosphor, ballast type and ballast quality. Higher wattage CFLs and those operating on electronic ballasts tend to be more efficient. Most early CFLs used magnetic ballasts, typically heavier and less efficient than their electronic counterparts. Flicker, hum and long start up times are also associated with magnetic ballasts. Electronic ballasts are now more common and suffer from fewer drawbacks, being silent, lighter-weight and more efficient. These systems are often 'instant start' which means the bulb will light up immediately, although it may still take up to three minutes to reach full light output. Certain electronic ballasts also allow dimming of CFLs, but these are expensive and only operate with four pin bulbs at present. Dimmed light from a CFL tends to be bluish, rather than reddish (as with incandescents), which may not be the desired effect (Frantzell pers comm 1997).

It is easier to direct the light from a CFL than from a strip light, although the light from a CFL has an asymmetric intensity distribution, unlike the uniform light distribution from a standard incandescent bulb. The distribution also varies along the axial and radial axes and differs with the shape and type of CFL. This is an important factor to consider when selecting an appropriate luminaire for a CFL to ensure that the light distribution is optimised. Other considerations are bulb orientation and temperature. Standard CFLs operate best in a base up (ie with tube downwards) position - light output decreases by up to 13% in a base down position, although this varies between different bulb types. Lifetime and output are affected by extremes of temperature. Sensitivity to these two factors is reduced in amalgam CFLs that have had certain alloys added to the mercury. Philips have used this type of CFL in their new enclosed 'pear-shaped' version.

1.1.3 Economics of CFLs

A primary reason for using CFLs is the savings that can be achieved in terms of energy and running costs, which benefit both the householder and society as a whole. Due to their higher efficacy, a 15W CFL can provide the equivalent light output to a 60W incandescent bulb. This represents a reduction in wattage of over 75%. A CFL also lasts around ten times as long as an incandescent. The high initial cost of a CFL, currently around 10-20 times the price of an incandescent bulb, can be paid back rapidly through the resultant energy savings and avoided cost of replacement incandescent bulbs. The actual length of the pay back period is dependent on the annual operating hours as well as the relative bulb prices and the cost of electricity. A three to one ratio for the replacement CFL wattage has been assumed in the cost-effectiveness calculation to allow for manufacturers over-rating CFL performance, as has happened in the past (see Section 2.1.4). This gives a conservative estimate for the cost-effectiveness of CFLs - the pay back periods will be even shorter if the more usual four to one ratio is used (ie replacing a 60W GLS bulb with a 15W CFL). Assuming an average price of 14 ecu for a CFL, 0.7 ecu for a GLS bulb and 0.12 ecu/kWh for electricity (based on the country profiles in Chapter 4), a 20W CFL replacing a 60W GLS bulb used for 3.5 hours a day will have a simple pay back of 2 years (Figure 2-1). With a lower price of 5 ecu for a CFL, representing either a pin-based CFL or a further decrease in the cost of an integral ballast CFL, it becomes cost effective to install CFLs in locations used only for an hour a day.

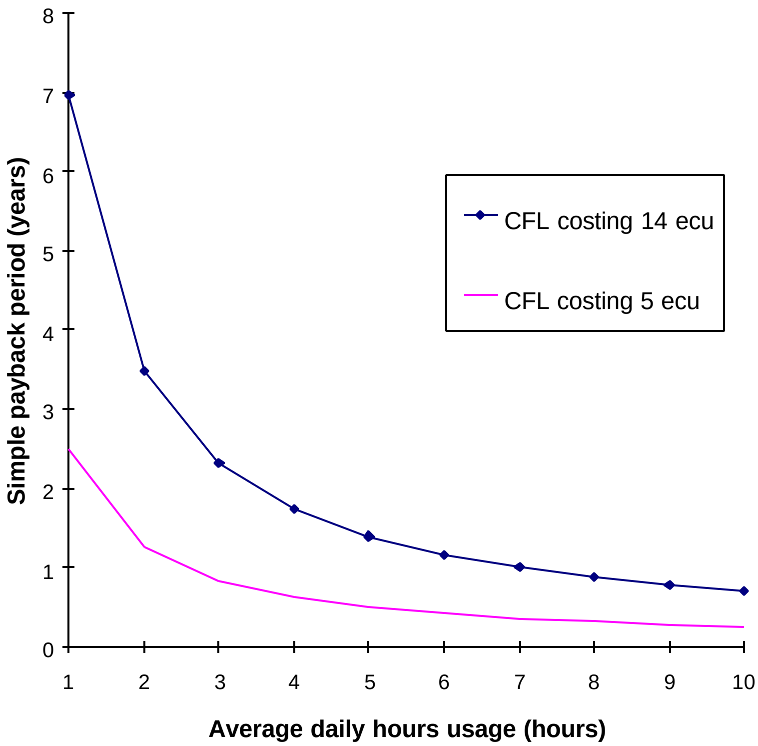


Figure 1-1 Cost-effectiveness of CFLs

1.1.4 CFL myths and concerns

Although the economics of using CFLs can be favourable, there are a number of confusing messages about CFLs in existence which discourage people from using them. A major problem is lack of knowledge among consumers about the characteristics of CFLs and how to use them appropriately, exacerbated by the wide range of CFLs currently available and the rapid advances that have been made in the technology. While some concerns expressed about CFLs are well founded, they do not always take the full picture into account. Other concerns may be due to bad experiences with the early technology or low-quality products and do not apply to the high quality CFLs now available. Mis-conceptions about the performance of CFLs are often the result of mis-application of the technology.

Mercury and disposal

It is true that CFLs contain mercury whereas incandescent bulbs do not - this is an important issue when it comes to disposal of the bulbs. However, pollution resulting from the electricity used by these bulbs is often overlooked - mercury emissions from fossil fuel electricity generation are around three times greater for incandescents than for CFLs. Mercury emissions from power plants cannot be recycled, unlike mercury contained within the CFLs. Also, further reductions in mercury pollution for a given amount of light are possible through the use of more efficient ballasts, which extend the life of the CFL (Mills 1993, Begley and Linderson 1991, Gydesen and Maimann 1991).

CFLs typically contain about 5 mg of mercury, which is actually six to eight times less than conventional fluorescent strips and has decreased from 15mg (DEFU 1996). This is likely to decrease further as the technology continues to improve - there are already CFLs on the market containing only 3 mg per bulb (Lundberg 1997). However, in the meantime, there need to be systems in place, easily accessible to the general public, for the proper disposal of these light sources. Both mercury and phosphors from discarded fluorescent sources can be recycled. Mercury-containing light sources are classified as hazardous waste in Austria, Belgium, Germany, the Netherlands and Switzerland. There are already recycling systems in place across Europe - in 1993, Germany had the largest bulb collection infrastructure in the world (Mills and Borg

1993). Osram has also become involved in developing appropriate recycling equipment (DEFU 1996) and in Sweden, it is possible to deposit used fluorescent lights at IKEA furniture stores for mercury recycling (Lundberg 1997). Integral ballast CFLs are more wasteful than pin based CFLs, since both the bulb and ballast are discarded, and are more costly to recycle because the ballast has to be separated from the bulb.

Hence, the use of CFLs, instead of incandescents, actually decreases levels of mercury pollution and the mercury is in a form that is easier to reclaim. Therefore, with appropriate disposal mechanisms in place, the presence of mercury in CFLs need not discourage their wider use.

Total harmonic distortion and power factors
Utilities are often concerned with the effect of CFLs on the electricity transmission systems through harmonic distortion. The choice of ballast affects the extent to which power quality is disturbed. Most ballasts now have high power factors giving low total harmonic distortion as well as being more efficient. Studies have demonstrated that CFLs actually have very little adverse effect on the power quality of the supply network (Gothelf 1997, Stymne 1997, DEFU 1996, Audin *et al* 1994, Jennings 1993) and may even reduce voltage distortion (Gothelf 1997). The major causes of harmonic distortion in the domestic sector were found to be TVs, videos and computers. There is still a great deal of debate over this issue, but with high power quality products now common, such concerns are of less relevance.

Improvements in technology
Electronic ballast CFLs represent a major improvement on magnetic ballasts, typically being 75% lighter in weight and 50% smaller in volume (DEFU 1996) as well as being more efficient and producing light of a better quality. However, most consumers are unaware of the difference between the two ballast types and incorrectly assume that any difficulties experienced with magnetic ballasts are true for all CFLs. Those people who bought magnetic ballast CFLs when they first appeared on the market may not realise that the technology has now vastly improved. Unfortunately, inferior magnetic ballast CFLs have not yet been eliminated from the market. These are often available at a much lower price than the electronic equivalent and so are likely to be the first type of CFL people try, leaving them with a bad impression of the technology. The image of CFLs is also damaged by cheap, low-quality electronic ballast CFLs which give poor light quality and often fail early. People need advice and guidance as to the best products and applications, which could be provided through labelling or by publishing a list of recommended products, as in Denmark and Sweden. The technology is continually improving and changing, with bulbs that are smaller, lighter and of different shapes. While this provides greater flexibility, it also adds to the confusion and may mean a lack of confidence among consumers in the continuity of the technology.

Some of the problems often associated with CFLs include:

1. *Size and bulk*
   Integral magnetic ballast CFLs are often large, bulky and heavy making it difficult to use them in existing fixtures. Electronic ballast CFLs are typically smaller and lighter in weight and therefore may be suitable for use in a wider range of fixtures. Such problems are not relevant to dedicated systems, since the fixture is designed around the CFL and the bulb is smaller and less heavy because it does not include the ballast.
2. *Flicker, noise and start up delay*
   Flicker (light modulation), hum and a long start up delay are often experienced with magnetic ballasts, but can be avoided by using electronic ballasts. However, even with ‘instant start’ electronic ballasts, where the bulb comes on immediately, there may still be delay of up to three minutes before full light output is reached which may be inappropriate in some cases. Manufacturers are working to reduce this start-up time further (DEFU 1996).

3. *Switching effect*
CFLs operating on magnetic ballasts and those using low-quality electronic ballasts are sensitive to frequent switching. However, tests on high quality electronic ballast CFLs indicate that their operating life is unaffected by frequent switching, based on a cycle of three minutes on and five minutes off for up to 20 000 ignitions (Pedersen 1997, Stiftung Warentest 1995).
4. *Radioactivity*
The starting mechanisms of magnetic ballasts contain small amounts of radioactive isotopes to ensure good starting performance. The resultant alpha and beta radiation is absorbed by the material enclosing the ballast. Gamma radiation is also emitted, but at low levels, thought to be negligible for humans (ELC 1990). Therefore, radiation is not necessarily a problem while the CFL is in use, but proper disposal of these bulbs is important. Electronic ballast CFLs have the advantage that they do not contain any radioactive material since they use a different starting mechanism.
5. *Health*
Many people are concerned about the health implications of using fluorescent light (Beckstead and Boyce 1992). This may be related to concerns about mercury or radioactivity, but is more often due to flicker from the lights. Studies in Sweden have found that people hypersensitive to electricity are affected by flicker from fluorescent lights on conventional magnetic ballasts. This was not such a problem with high frequency electronic ballasts (Lundberg 1996).
6. *Poor light quality*
CFLs are often thought to give a poor quality of light, both in terms of the colour and brightness. While this may have been true of earlier technologies, developments in the phosphors used have led to improvements in the colour temperature of CFLs, resulting in a warmer light. However, the light from many low-quality bulbs is still poor, damaging the image of higher quality products. There are also a number of other reasons for light output to be lower than expected. CFL efficacy varies with wattage and the ballast used, affecting light quality. Light output diminishes by up to 30% with age and is sensitive to temperature and operating position. In addition to this, manufacturers often overstate CFL performance. Allowing for such factors, it is better to use a three-to-one wattage equivalence between CFLs and incandescents, rather than the usual recommended four or five-to-one ratio (ie replacing a 60W GLS bulb with a 20W CFL, rather than 11W or 15W). The performance of the CFL is also dependent on the fixture it is used in - this is covered next.

Mis-application of the technology

Even purchasing a high quality product does not guarantee satisfaction, particularly when using integral ballast CFLs in fixtures designed for incandescent bulbs. CFLs are not appropriate for all applications where incandescents are normally used, such as accent lighting where a bright focused beam of light is required. One of the most important factors to consider is the different light distributions of CFL and GLS bulbs. For instance, in fixtures designed for the downward light distribution of GLS bulbs, the shade would block light emitted in the horizontal plane by a CFL. This difference in light distribution also means that CFLs do not work well with reflectors designed for an incandescent bulb. Obtaining optimum performance from a CFL is not simply a case of buying a bulb of the correct wattage and installing it in the fixture, as it is with GLS bulbs. There are additional considerations to take into account, such as bulb orientation and operating temperature. Most householders are unlikely to be aware of all these issues and there is a risk that they will install CFLs in an inappropriate fixture or location leading to dissatisfaction and a negative perception of the bulbs. Therefore, when people claim that CFLs are not bright enough or give a poor light quality, it is more likely to be because of mis-application of the technology rather than a fault of the CFL itself.

1.2 LIGHT FIXTURES

There is a vast array of different light fixtures available, reflecting the number and diversity of fixture manufacturers throughout Europe. With any light source, the fixture is crucially important in determining the distribution and quality of light provided by the luminaire. However, most people buy fixtures on the basis of their appearance and design with little consideration of this interaction with the light source. The broad classifications used in this study are useful when considering the suitability of fixtures for use with CFLs and how to influence this market.

There are three main classes of fixture: ceiling mounted, wall mounted and free standing. Ceiling fixtures can be further subdivided into pendant, surface and recessed. Free standing fixtures can either be floor standing or table/desk lamps.

Fixtures can also be classified by the way in which they are installed in the house (ie whether they are fixed or portable). Fixed light fixtures are typically located on the ceiling or wall and operated by a wall mounted switch. These fixtures may be wired into a separate electrical circuit solely for lighting. Portable fixtures are those with a switch either on the fixture itself or on the cable and which plug into a wall socket, connected to the general electrical circuit. While free standing fixtures are always classified as portable, wall and ceiling fixtures may be classed as fixed or portable in different countries, depending on how the lighting is installed. Specification of light fixtures during the building of a house and hence the extent to which the fixed light fixtures are actually considered to be part of the house and are left behind when people move, also varies between countries.

The majority of fixtures currently available on the market and installed in people's homes are designed for GLS bulbs, with a bayonet or screw socket. Pin based halogens and fluorescent light sources require different fixtures with the appropriate socket and transformer or ballast.

Dedicated systems for CFLs, where the ballast is incorporated into the fixture, are already widely used in the commercial sector but are not yet common in households. These systems have a number of advantages over the use integral ballast CFLs in existing GLS fixtures - they solve some of the technical problems associated with the use of integral units, making energy savings simpler as well as providing better light quality:

- GLS and CFLs have different light distributions. Fixtures specifically designed for CFLs will be appropriate to the light distribution from a CFL.
- Incorporating the ballast into the fixture means that the size of the CFL is reduced, allowing more flexibility in fixture design.
- CFL dedicated fixtures ensure optimal performance of the light source since they are based on the characteristics of the CFL.
- A ballast usually lasts for 40 000 to 60 000 hours and so can power around five to six CFLs over its lifetime. Therefore, incorporating the ballast into the fixture minimises waste and reduces the cost of replacement bulbs. This makes the economics of CFL replacement more favourable.
- Pin based CFLs are cheaper and easier to recycle than integral ballast CFLs.
- The savings from using CFLs in dedicated fixtures are guaranteed since there is no possibility of returning to the use of GLS bulbs in these fixtures.
- The use of pin based CFLs for dedicated systems, rather than requiring different bayonet and screw based bulbs, could facilitate harmonisation of the residential bulb market across Europe.

There are also some disadvantages with current dedicated systems which need to be tackled before their use can become more widespread:

- Not all CFLs and ballasts are compatible - bulbs above 9W often require different bases and ballasts for each wattage and are therefore not interchangeable. This is a major barrier to the wider use of dedicated systems.
- Since the ballast lasts for around six CFLs there needs to be a guarantee that replacement bulbs will be available in the future, within the lifetime of the fixture. A ballast in a fixture used for three hours a day could still be functioning after 50 years, although the fixture will probably have been replaced by then.

1.3 CONCLUSIONS

Since the widespread introduction of electric lighting into homes at the beginning of this century, incandescent light sources have been the dominant technology. Some of the initial barriers to the installation of incandescent lighting are similar to those currently being experienced in the CFL market. For instance, CFLs are a relatively new technology, not yet widely used, even though the first CFLs appeared on the market almost twenty years ago. Whilst CFLs can be used in the existing light fixtures, they perform better when used in specifically designed fixtures, as was the case with using incandescents in fixtures designed for gas lamps. It took over forty years for incandescent fixtures to become common - this process needs to be quicker for CFLs.

CFLs are a different and unfamiliar technology compared to traditional incandescents. There is a great deal of confusion about them among consumers, preventing their wider use. This is partly a result of bad experiences with the early magnetic ballast CFLs, some of which are still available on the market, perpetuating negative opinions about CFLs. Low-quality bulbs are also detrimental to the image of CFLs. The interaction between the light source and the fixture is crucial in generating the required distribution and quality of light. Mis-conceptions about the performance of CFLs are exacerbated by the fact that the majority of fixtures on the residential market are designed for incandescent bulbs and are therefore not always suitable for use with CFLs. The use of dedicated fixtures tackles many of these issues, as well as improving cost-effectiveness and reducing wastage. However, there needs to be greater continuity and compatibility of the bulbs and ballasts used in these fixtures, with a greater range of fixture designs, if they are to be successful.

CHAPTER 3: RESIDENTIAL LIGHTING MARKET

An appreciation of the structure and players involved in the lighting industry is necessary to understand how this market can be influenced. There is an interplay between what is available on the market and the perception of lighting in any one country.

The residential lighting market is more complex than markets for other domestic appliances since it consists of two inter-dependent sectors: light bulbs and light fixtures. These two markets have quite different structures, the light bulb market being similar across Europe in terms of manufacturers, products and retail outlets, whereas the light fixture market is more diverse and country specific.

Sales data for both these markets are sparse and, where data are available, the distinction between the residential and commercial sectors is often unclear. Actual data on residential light bulb sales are only collected in a limited number of European countries at present, with differences in level of detail, coverage of the market and the different bulb types. With the current moves to establish European wide data collection, these differences need to be resolved and coverage increased. Data on fixture sales are also limited and typically only given in terms of value which is of limited use compared to volume sales data.

The following section gives a broad overview of the residential lighting market in Europe (in some cases limited to countries within the EU), covering manufacturers and retailers, and discusses the aspects of the market that influence the successful introduction of CFLs.

2.1 MANUFACTURERS

2.1.1 Light bulbs

Across Europe, the majority of light bulbs for both residential and commercial use are produced by three major light source manufacturers: Philips, Osram (Siemens) and GE Lighting (Tungsram, Mazda). Their headquarters are located in the Netherlands (Philips), Germany (Osram) and the USA (GE Lighting), although production is world-wide. These companies each account for around 30% of residential light bulb sales in Europe. There may be slight variations in the wattage or type of bulb sold in each country, for example, pin-based CFLs of a higher colour temperature are sold in Spain because these give a brighter light (Beronius pers comm 1998) and GE Lighting produces CFLs in six different colours for different countries (DEFU 1996). But, on the whole, products do not differ significantly between countries. The UK and Ireland represent an exception because of the requirement for bayonet based bulbs in the residential sector. French households also use bayonet based bulbs to a certain extent, although screw-based bulbs are more common. A further difference in the UK is that the public electricity supply operates at around 240V, rather than 230V supply in the rest of Europe. Hence specific incandescent bulbs must be produced for the UK, because their life time and light output is sensitive to voltage. The Europe-wide harmonisation of electricity supply to 230V (+/- 10%) by the year 2003 means that manufacturers have to adapt their products accordingly. This is of particular relevance for incandescent light sources, unlike electronic ballast CFLs.

2.1.2 Light fixtures

The crucial difference between the bulb and fixture manufacturing industries is that there are hundreds of relatively small fixture manufacturers, generally specific to each country, rather than a few multi-national organisations. This is an important factor to consider when it comes to influencing the market, as is the extent to which fixtures are imported into Europe and their country of origin. The disparate nature of this industry makes the collection of information difficult. Actual data on the light fixture market were obtained for only eight of the EU countries (Austria, Belgium, France, Germany, Italy, Netherlands, Spain, UK) and only in terms of value, not volume. As with the bulb market, there are also difficulties in apportioning production and sales between the residential and non-residential sectors. Despite these limitations, it is still possible to give a general overview of the European market.

Unlike the light source industry, companies involved in the fixture industry do not tend to operate in both the residential and commercial sectors. In 1995, the top three producers of residential fixtures were Massive (Belgium), Emess (UK) and Hustadt (Germany). The top 50 companies in this sector represent only 27% of production, illustrating the small scale of companies. By comparison, in the non-residential lighting market, over 80% of production is concentrated in the top 50 companies. Philips is particularly prominent in the non-residential sector, responsible for 12% of total production in all sectors in the countries covered (CSIL 1996).

The residential fixture market in the eight countries covered is worth in the region of 5 billion ecu in 1995 (derived from CSIL 1996), representing around 55% of the fixture market for all sectors. Table 3-1 summarises the market in terms of sales, production and numbers of companies in each country. Germany is the leading producer, although with relatively few companies. Belgium, Italy and Spain are the only net exporters of residential light fixtures. Italy is the major exporter, exporting mainly to Germany and France, and also has the largest number of manufacturing companies.

Table 2-1 European residential fixture market

	Sales 1995 (million ecu)	Production 1995 (million ecu)	Number of companies
Austria	185	156	n.a.
Belgium	126	145	n.a.
France	497	409	130
Germany	1687	1512	150
Italy	639	1338	350
The Netherlands	272	102	n.a.
Spain	391	475	220
Scandinavia (S, DK, N)	318	289	n.a.
UK	630	485	320
Total	4745	4911	1170

Source: CSIL 1996
Note: n.a. - not available

A high proportion of trade is within Europe, the majority of fixtures sold being manufactured in Europe. Levels of production and export from the Eastern European countries are increasing due to direct investment by Western European companies. As with the bulb market, there is also increasing competition from Far Eastern imports. Table 3-2 shows the international trade figures for seven of the EU countries (Belgium, France, Germany, Italy, Netherlands, Spain, UK), indicating the balance of trade between the various regions. These figures cover both the residential and commercial sectors - it is not possible to identify the relative proportions for each.

Table 2-2 International trade in light fixtures (all sectors)

	Exports (million ecu)	Imports (million ecu)	Balance (million ecu)
Europe	2121.3	1649.0	472.3
Asia	348.3	452.4	-104.1
America	165.3	53.2	112.1
Africa	72.5	10.7	61.8
Other	43.9	3.5	40.4
Total	2751.3	2168.8	582.5

Base: Belgium, France, Germany, Italy, Netherlands, Spain, UK
Source: CSIL 1996

Data broken down by fixture type (ceiling, wall and free-standing) are more difficult to interpret because of variation in prices within and between the different classes. In the residential sector, ceiling fixtures represent the majority of production, in terms of value, for all countries. This category tends to be at the higher end of the price range and so this does not necessarily reflect a correspondingly high volume of sales.

Data obtained on fixtures were also classified by style in broad categories of ‘traditional’, ‘modern’ and ‘design’. This is not particularly informative, with most countries producing a mix of traditional and modern designs. Exceptions are the Netherlands and Scandinavia, with a high percentage of production being modern designs.

In addition to variation in aesthetic requirements, the requirement for bayonet sockets in the UK and Ireland limit the extent to which the European fixture market can be harmonised.

2.2 RETAILERS

Despite differences in the manufacturing industries, the retail structure for lighting appears to be similar in most European countries, with limited overlap between bulbs and fixtures. There are five main types of retail outlet:

1. Supermarkets
2. DIY (Do-it-yourself) stores
3. Department stores
4. Furniture stores
5. Lighting specialist stores

Light bulbs are sold in all five outlets although the range available varies. Supermarkets tend to stock mainly incandescent bulbs, but CFLs are becoming more common. Lighting specialists usually have the most extensive range of bulb types, particularly of CFLs and halogens. Department stores, furniture stores and DIY outlets lie somewhere in between these two extremes. In recent years, some DIY stores have been selling cheap CFLs (3-5 ecus each) to attract more customers. However, throughout Europe, most people buy their replacement bulbs in supermarkets as part of their regular shopping trips.

Supermarkets do not sell light fixtures, therefore people have to buy their fixtures in a different place to where they normally buy bulbs, although the type of bulb they buy is actually dictated by the fixtures they own. Fixtures are sold in the other four outlets, with a trend towards increasing sales through DIY stores at the expense of sales in furniture and department stores. Residential light fixtures are not only purchased by householders - builders and architects are both involved in the specification and purchase of light fixtures for the home but may use different distribution channels, such as a wholesalers.

No breakdown of sales value was available by the different outlets for the residential market alone. For the total fixture market, lighting specialists sell 19% of all fixtures compared to 7% in both DIY and department stores and 5% in furniture stores (CSIL 1996). The remaining percentage is non-residential sales. Since these percentages are based on sales value and lighting specialists are likely to sell more expensive fixtures, volume sales may be more evenly distributed through the outlets.

Sales volume data provide information on the rate of turnover of bulbs and fixtures in the stock. Such figures are necessary to appreciate the time-scale for the introduction of a new technology, such as CFL dedicated fixtures, through natural turnover in the stock. The turnover of bulbs in the average house, derived from sales and ownership data, forms the basis of the stock models which estimate residential lighting electricity consumption and are discussed in Chapter 8. Turnover is more difficult to derive for fixtures since data are in value rather than volume of sales. The figures in Table 3-1 indicate that, across the 140 million households in the eight countries, the average household spends around 33 ecu per year on fixtures. This is assumed to be equivalent to the purchase of one fixture each year per household across the EU, either new or replacement. These figures are supported by a recent survey in the UK which found that two-thirds of respondents had purchased a fixture in the previous six months, the majority of people spending up to 38 ecu on their purchase. People were most likely to spend over this amount for floor and ceiling fixtures (Pearce pers comm 1997).

2.3 The market for CFLs

CFLs first appeared on the European market in the early 1980s although the year of introduction in individual countries varies, the most recent being in Eastern Europe. From the outset, CFLs have been looked upon as a direct replacement for incandescent bulbs, focusing on the use of integral ballast CFLs in the existing fixtures. People need guidance on the appropriate application of these bulbs but this is not easy given the current structure of the lighting market. People are not used to having to seek advice about how to use their light bulbs. Also, since many people buy their bulbs in supermarkets, informed retail staff are not available to give such advice and they cannot observe the interaction between the bulb and fixture to help choose the most suitable bulb. Even most lighting retailers do not usually display CFLs in luminaires in their showrooms.

In 1997, global sales of CFLs to all sectors were around 356 million, with 120 million sold in Europe, being split almost equally between pin-based and integral ballast bulbs (Borg 1997). Electronic integral ballast CFLs are replacing the earlier magnetic ballast technology. The proposed EU directive, improving the efficiency of ballasts on the market, will help formalise this trend. In Western Europe, the CFL market has been increasing steadily at around 10-15% per annum over the past four years, with a slight decrease in GLS sales during this time period. In order to meet the increasing demand, manufacturers are investing in new production plants, mainly in Eastern Europe (for example, Tungsram in Hungary) and developing countries, where labour costs are lower. China has now taken over from the USA as the world's single largest CFL producer (Nelson 1996). In the past, CFLs imported from the Far East have typically been cheaper but of poor quality. However, the quality of these bulbs appears to be improving. In 1997, both Philips and GE lighting purchased CFLs from independent Chinese manufacturers to sell under their own labels (Borg 1998).

There is a lack of fixtures suitable for CFLs on the residential market, both those for use with integral ballast CFLs and fixtures dedicated to CFLs, although there is a wide range of dedicated fixtures in the non-residential sector. Manufacturers claim that it is lack of interest from the retail sector that is the major barrier. This appears to be borne out by a survey of manufacturers and retailers in Sweden (Brunnström 1997). Although all retailers surveyed stocked at least one CFL fixture, the range was very limited. In terms of manufacture, dedicated fixtures represented 31% of ceiling and 25% of wall fixture production. While these proportions are still relatively low, it does indicate that there is a greater range of CFL fixtures manufactured than currently found in retail outlets.

Production of CFL fixtures requires close liaison between the bulb and fixture manufacturers to ensure compatibility and continuity of technologies used in the fixtures, such as the bulbs and ballasts. In the past, there has been no particular need for these two industries to collaborate, since the technology has not changed drastically. However, the introduction of halogen lighting required the design and manufacture of special fixtures, with sockets for pin based bulbs. There is now a vast array of dedicated halogen fixtures on the market, demonstrating that collaboration between the two industries is possible and can be highly successful. This may have been partly because designers and manufacturers look upon halogens as an exciting light source and enjoy working with it.

The involvement of designers is crucial - people tend to buy fixtures because they like the design and so there needs to be attractive and original CFL fixtures available. However, in 1995, only 1.9% of turnover was invested in product design across both residential and non-residential fixture manufacturers (CSIL 1996). Current CFL fixture designs are often based around traditional GLS fixtures, which are not necessarily appropriate. Student competitions in both Sweden and the UK have produced innovative designs which optimise the shape and properties of a CFL, rather than treating it as a replacement incandescent bulb. EM (the Swedish National Energy Administration) are aiming to encourage liaison between designers and fixture manufacturers in the production of CFL fixtures through a programme subsidising the designers costs. NOVEM, the Dutch Energy Agency, is considering setting up a similar scheme.

2.4 CONCLUSIONS

The two lighting industries, light sources and light fixtures, are quite distinct in terms of manufacturers and there is currently little collaboration between the two. The size and type of companies involved are very different, the three major bulb manufacturers being universal across Europe and between sectors, whereas the fixture manufacturers are smaller, more country specific and focused on the residential sector. Despite some similarities in the retail structure, there is a disparity between bulbs and fixtures since most people buy their replacement bulbs in supermarkets, where fixtures are not available. This does not give people the opportunity to look at how the bulb and fixture interact. While this is not an issue when purchasing incandescent bulbs, it becomes more important with CFLs. Households within the EU are thought to purchase an additional or replacement fixture each year, representing an opportunity to introduce dedicated fixtures into peoples' homes. The current retail structure, lack of informed retail staff, lack of collaboration between the manufacturing industries and lack of dedicated CFL fixtures are all obstacles to the success of CFLs.

CHAPTER 4: EUROPEAN OWNERSHIP AND CONSUMPTION

Residential lighting is not an area which has been studied in detail within the majority of European countries, let alone across Europe. Information in this sector is sparse and difficult to obtain, with knowledge dispersed between utilities, government departments, research agencies, consultants, manufacturers, retailers and consumers. Market data specific to the residential sector are poor. Other data, such as household lighting electricity use and the number of bulbs per household, are often rough estimates with little research done to confirm these figures. In studies which have monitored other domestic electricity end uses, lighting is often relegated to a miscellaneous category due to difficulties in identifying how much electricity goes into the lights.

This lack of knowledge and research has two consequences: it is possible that estimates of residential lighting electricity consumption are inaccurate and domestic lighting is therefore not considered to be an important area from a policy perspective. Secondly, without a reliable base line, it is not easy to identify or evaluate any savings that can or have been made.

As part of this project, data relevant to lighting were collected for all fifteen EU countries as well as six associate members and assembled into ‘country pictures’, building up a comprehensive picture of residential lighting in homes across Europe. These profiles represent the best currently available information obtained from the various sources in each country and serve several purposes. They:

- provide a useful source of information for each individual country,
- allow comparisons between countries,
- identify gaps in the information and therefore indicate areas for future research,
- highlight inconsistencies in the numbers and where more reliable figures are needed,
- provide the context for the detailed studies of Germany, Sweden and the UK, undertaken as part of the DELight project,
- enable some key indicators for domestic lighting to be identified
- establish the context for residential lighting policy, both at a national and EU level

The country profiles cover basic data, such as ownership and lighting electricity consumption, as well as people’s attitudes to lighting, with a particular focus on CFLs. The key figures are shown in Table 4-1 while the individual profiles are included in Chapter 2 of the Supporting Material, with a full list of references used. Care should be taken when making comparisons between countries because of the low confidence in some of the figures. The following summary highlights the important findings.

3.1 ELECTRICITY CONSUMPTION

On the basis of the data collected, total residential lighting electricity consumption in the 15 EU countries is about 86 TWh, representing 17% of EU domestic electricity consumption. This lies between cold (refrigerators, fridge-freezers and freezers) and wet (washing machines, tumble dryers and dishwashers) appliances which account for around 23% and 12% of EU domestic electricity consumption respectively. Average household lighting electricity use ranges from 240 kWh pa to 920 kWh pa across Europe, as illustrated in Figure 4-1. Although average hours of daylight are the same for all countries across the year, hours of artificial lighting are expected to differ, with a general downward trend from North to South, which should be reflected in electricity consumption. Assuming this to be true, figures for lighting electricity use appear to be too low for Belgium, Lithuania and the Czech Republic and too high for Spain and Portugal. The majority of figures given are rough estimates, with only three validated by actual measurements of lighting electricity use in households (Bulgaria, France, UK). This indicates the need to revise some of these estimates.

Table 3-1 Domestic lighting in Europe: summary of individual country profiles

Country	Households (millions) 1994	Household area (m^2)	kWh (per hh pa)	kWh/ m^2	Bulbs (per hh)	H'holds with CFLs 1997	CFLs (per hh) 1997	CFLs (per owning hh) 1997	Electricity price 1996 (ecu/kWh)	GLS price (ecu) 1997	CFL price (ecu) 1997
Austria	3.1	87	345 [1995]	4.0	*no data*	*no data*	*no data*	*no data*	0.13	0.9	15
Belgium	4.0	86	291 [1994]	3.4	31	29%	0.9[1993]	3.7	0.16	0.9	18
Bulgaria	3.0[1992]	*no data*	350 [1994]	*no data*	11.8	1.4%[1994]	0.02[1994]	1.3[1994]	*no data*	1.0	14
Czech Rep.	*no data*	*no data*	250 [1997]	*no data*	*no data*	*no data*	*no data*	*no data*	0.004	0.3	11
Denmark	2.4 [1996]	107	585 [1997]	5.5	26	46%[1995]	2.0[1995]	4.4[1995]	0.17	1.0	16
Finland	2.2 [1995]	76	920 [1993]	12.1	*no data*	*no data*	1.0[1995]	*no data*	0.09	0.5	20
France	22.8	81	500 [1994]	6.2	18.5	*no data*	0.5	*no data*	0.13	1.2	17
Germany	36.3	83	775 [1997]	9.3	30	51%	2.1	4.3	0.16	1.0.	10
Greece	4.0	80	310 [1988]	3.9	4.7	11.5%[1995]	0.1[1995]	1.0[1995]	0.11	1.0	13
Hungary	*no data*	*no data*	*no data*	*no data*	*no data*	20%	*no data*	*no data*	*no data*	*no data*	*no data*
Ireland	1.3	92	438 [1996]	4.8	25	22%[1996]	0.9[1996]	4.0[1996]	0.11	0.6	15
Italy	24.4[1995]	*no data*	296 [1995]	*no data*	20	55%[1995]	1.1[1995]	2.0[1995]	0.14	0.7	14
Lithuania	*no data*	58	240 [1997]	4.1	*no data*	*no data*	*no data*	*no data*	0.05 [1997]	0.3	15
Luxembourg	0.15	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	0.12	*no data*	*no data*
Netherlands	6.4	105	528 [1996]	5.0	36	62%	2.7	4.5	0.09	0.7	11
Poland	12.9[1996]	64	600 [1997]	9.4	16	19.6%	0.3[1995]	1.6[1995]	*no data*	0.3	9
Portugal	3.2	89	425 [1995]	4.8	*no data*	*no data*	*no data*	*no data*	0.16	0.5	13
Romania	7.8[1995]	*no data*	*no data*	*no data*	9	0.5%[1995]	0.006[1995]	1.1[1995]	0.02	0.3	13
Spain	12.0	86	500 [1995]	5.8	29.5	11.5%[1995]	0.2[1995]	1.7[1995]	0.16	0.6	13
Sweden	4.1[1995]	110	760 [1997]	6.9	40	10%	0.4	4.0	0.08	0.6	13
UK	24.3[1996]	84	720 [1996]	8.6	20	23%	0.7	3.0	0.10	0.8	15
EU Total	150	-	86 TWh	-	-	-	138 million	-	-	-	-
EU Average	-	88	569 kWh/hh	-	24	32%*	0.9/hh	2.8	0.12	0.8	15

*Based on available data (excluding Austria, Finland, France, Luxembourg and Portugal)

Note: Full references are included in Chapter 2 of the Supporting Material

When lighting consumption in the UK was assessed through detailed modelling, previous estimates were doubled (Palmer 1997, DECADE 1995). Actual measurements of lighting electricity use confirmed this revision (Electricity Association 1998), hence validating the modelling techniques used. This provides confidence in the revision to German household lighting consumption, giving a figure more than double prior estimates, through the use of the same modelling approach (Chapter 8).

Across the EU, the proportion of household electricity used for lighting varies from 7-27% between countries, depending on other electrical end-uses in the home, particularly heating. Within the home, lighting use is highest in the living room, accounting for around 40% of lighting consumption in Denmark and Greece. Comparing lighting electricity use by floor area implies that Finnish and Polish homes have the highest levels of lighting.

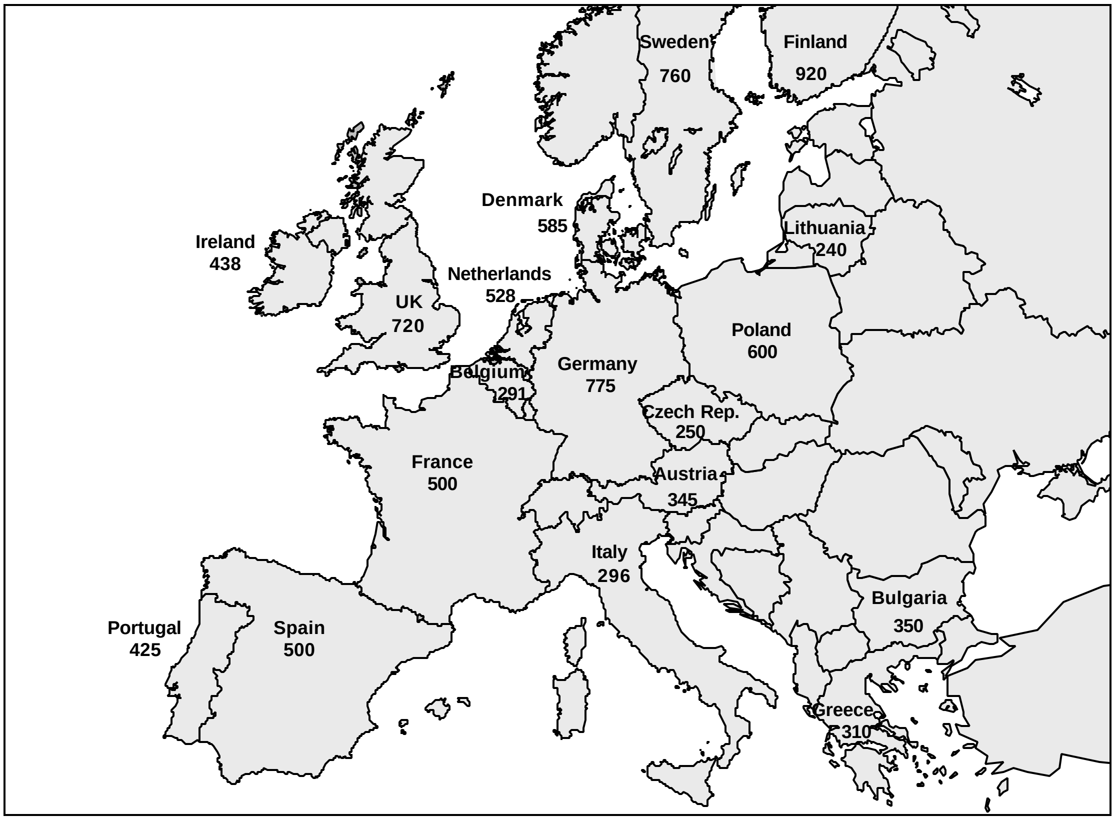


Figure 3-1 Average household lighting electricity consumption by country, Europe (kWh pa)

Even with reliable figures for lighting electricity use, variations between countries can be due to a variety of reasons. The number of bulbs, the wattage of these bulbs and their hours of usage are all factors which determine the level of consumption, although this is not a direct relationship. These variables are, in turn, influenced by a wide range of other factors such as the size of the house, number of people, household income, economics, aesthetics, country and culture. Trying to identify the key factors is difficult, although the number of people in the house has been found to be particularly important in Bulgaria (Yaneva and Welinov 1997) and the UK (Palmer 1997, Electricity Association 1998). Lighting electricity use has also been found to be strongly associated with income in the UK (Electricity Association 1998).

The trend towards increasing numbers of households, and particularly single person households, across the EU is likely to result in an increase in lighting electricity use.

3.2 OWNERSHIP

Across Europe, there is wide variation in the average number of light bulbs per household, ranging from 4 to 40, giving an EU average of 24. A high number of bulbs does not appear to be necessarily related to high levels of electricity use. However, it is difficult to establish if this is true, given the lack of confidence in some figures.

While data on the total number of light bulbs per household were available for the majority of countries, a more detailed split between the different bulbs in the house was more difficult to obtain. It is apparent that incandescent GLS bulbs are still the dominant light source in all countries, representing at least 70% of the installed bulbs. The most commonly used wattage is 60W. Fluorescent tubes are usually found in the kitchen, with an average of one or two per household in most countries. Ownership of CFLs is covered in section 4.4.

Halogen bulbs, both low and high voltage, are becoming increasingly popular throughout Europe, typically used in the living room and kitchen. A substantial amount of research has been done on halogen torchieres in the Netherlands, where ownership of these fixtures has rapidly increased within a short space of time (Kavelaars 1997). The concern is that the use of these high wattage bulbs negates any savings achieved through the installation of CFLs. Halogen lighting is also common in France, Germany, Italy and Sweden.

As with the market data, information on fixtures was also difficult to obtain. There are differences across Europe in both the style and type of fixtures found in the home. There appears to be a current trend in some countries towards a ‘Scandinavian way of lighting’ - a high number of fixtures with low wattage bulbs.

3.3 ATTITUDES

Differences exist between countries in the way in which lighting in the home is perceived, with variations in the type of lighting that people want and the level of interest they actually take in how they light their homes. Such attitudes may be determined by a number of factors such as culture, climate and the history of lighting. Based on the comments provided for the country pictures, the following section gives an overview of people’s views on lighting. Such a comparison is very general - there will, of course, be many variations within a country. There is a more detailed investigation into attitudes to lighting for Germany, Spain, Sweden and the UK in Chapter 7.

General interest in using light within the home to create atmosphere and ambience appears to be greater in Northern Europe, particularly among the Nordic countries. This is likely to be due to the long hours of darkness during the winter months and the colder climate - warm, cosy lighting, mimicking fire light, is popular. Since artificial lighting plays an important role in these people’s lives it may also explain why they are more fashion conscious in terms of the lighting they install in their homes, using fixtures of modern designs. Attitudes among people in countries slightly further South, such as the Netherlands and the UK, appear to be changing, with increasing interest in the way they light their homes.

In Southern Europe, the need for artificial lighting is more constant across the year since there are not such extremes in daylight hours between winter and summer. Also, hours of actual sunlight will be higher and people typically spend more time outside rather than in the house. The fact that artificial lighting is not so central in people’s lives is reflected in the apparent lack of interest that people take in lighting. They appear to be less concerned with the aesthetics of lighting, regarding it as something which is purely functional. In Portugal, for example, fixtures may not have a shade covering the bulb. Bright, white light is said to be preferred in Spain and Italy - creating a feeling of warmth is not so necessary in a warm climate.

The Eastern European countries are more limited by finances than tastes, although people are keen on modern technologies in Hungary and Poland. Modern European designed fixtures are expensive and are only found in higher income households in Lithuania.

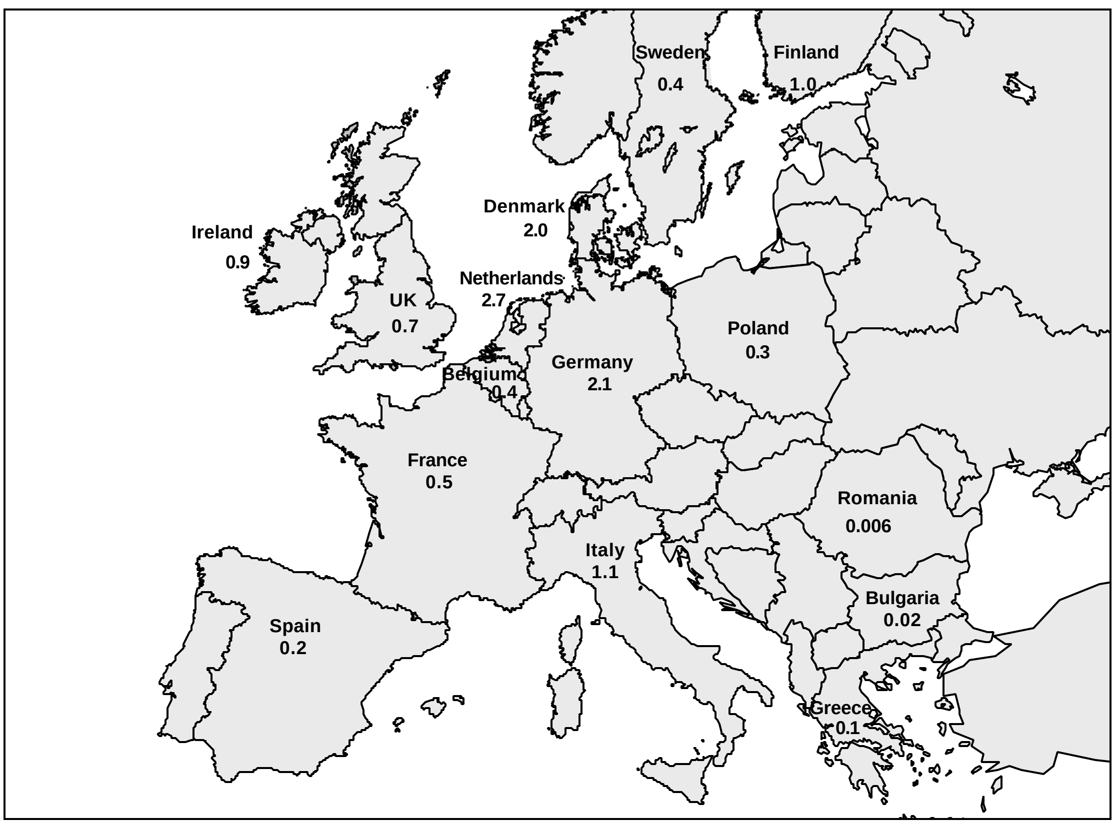
Opinions on incandescent light sources are similar throughout Europe: GLS bulbs are viewed as low maintenance, cheap and easy to replace. Halogens have a modern image, producing aesthetically pleasing light which is described as interesting and exciting. Fluorescent lighting often has a slightly negative image being functional but of poor light quality, although opinions on CFLs vary (see section 4.4).

3.4 CFLs

4.4.1 CFL ownership

Data from the country profiles indicate that there are over 130 million CFLs installed in approximately 30% of households in the EU, giving an average of 1 CFL across all households. However, there is a wide range of ownership between different countries, the Netherlands having the highest ownership level: 62% of households owning an average of 4.5 CFLs. Despite this range, those EU households that own CFLs have an average of three or four. Whether this indicates the existence of a barrier to installing more CFLs at this level or whether it actually reflects the fact that ownership has built up slowly over time is unclear.

Ownership of CFLs in the Eastern European countries is slightly lower, as would be expected given the relatively high price of CFLs compared to the average household income. CFLs are also a more recent introduction onto the market in these countries. The range of CFL ownership across Europe is shown in Figure 4-2.



Base: all households

Figure 3-2 Average number of CFLs per household by country, Europe

In general, ownership tends to be higher among larger (both in terms of size and number of people), higher income and educated households. The geographical concentration of high CFL ownership in the

Netherlands, Germany and Denmark is likely to be related to the length of time the bulbs have been available on the market. The headquarters of Osram and Philips also happen to be located in Germany and the Netherlands. Countries with the highest ownership tend to have the lowest relative price of CFLs compared to incandescents (10 to 16 times as expensive). These countries have also had a large number of campaigns, which have resulted in increased demand, reducing the retail price of CFLs. This is in stark contrast to the Eastern European countries, where CFLs are up to 50 times more expensive than incandescents and can be as much as a quarter of the average monthly wage.

Living rooms, hallways, dining rooms and kitchens are common locations for CFLs in most countries, all being relatively high use locations. They are often used for external lighting in Denmark and Sweden. The most popular CFL appears to be 11W, with 9W also common. In the UK, electronic ballast CFLs are more popular than magnetic CFLs, with four times as many electronic CFLs installed in British homes (Rowe pers comm 1997). This trend away from magnetic ballast CFLs is likely to be reflected in the rest of the EU, particularly when the proposed EU directive to phase out low efficiency ballasts comes into force.

4.4.2 Attitudes to CFLs

Despite the fact that CFLs have been available for almost two decades, there is still a lack of awareness of this technology and the range of different types available throughout Europe. Awareness is lowest in the Eastern European countries, although CFLs are a more recent introduction there. People sometimes confuse CFLs with halogens or fluorescent tubes.

Price is often quoted as the major barrier for those people who have not yet bought a CFL. Those households that own a CFL are generally satisfied with them and price is less of an issue. The key motivations for installing a CFL vary between countries. In Denmark, Germany and the Netherlands, the environmental benefits are important, whereas in Spain this does not seem to be a crucial factor in encouraging CFL purchase. In Southern Europe, people are positive about the quality of light from a CFL, since it produces the bright clear light that they prefer and so they may require fewer incentives to use CFLs. In the Eastern European countries, the cost savings are important. This is particularly because the price of electricity, which has been kept low in the past, is increasing, thus stimulating interest in energy saving measures.

The main benefits of CFLs are considered to be financial savings, long life, and therefore convenience. In Southern Europe the quality of light is also valued.

In the Northern countries, particularly Denmark, Finland, Germany and Sweden, the size and design of CFLs is unpopular. There are two reasons for this - the actual appearance of the bulb is felt to be unattractive and the shape and size of the CFL makes it incompatible with people’s fixtures. This is more of an issue in these countries because of the popularity of small low wattage fixtures. Lack of suitable fixtures is often quoted as a barrier to installing CFLs, particularly in Germany and the Netherlands. This issue is investigated in the technical survey (Chapter 6).

3.5 CONCLUSIONS

There is a lack of reliable information on residential lighting for many European countries, making comparisons between countries difficult. Where better information has been obtained, this indicates where other, less robust, figures may need to be checked. Detailed research has resulted in estimates of lighting electricity consumption being increased in Germany and the UK, raising the importance of this area in terms of policy. Establishing a reliable baseline is an essential step towards accessing the savings achievable in this sector.

Residential lighting consumption in the fifteen EU countries is around 86 TWh, representing an expenditure of 10.3 billion ecu. Lighting electricity use varies with floor space and the number of people in the home, but there are insufficient data to confirm the relative importance of these factors or others, such as geography and household income. Interest in lighting in the home appears to be growing, accompanied by an increase in the numbers of bulbs used - halogens being particularly popular. However, there are still 70% of households in the EU without a CFL. Those households in the EU that do own CFLs usually have around three or four out of an average of 24 bulbs in total per household.

CHAPTER 5: THE THREE CASE STUDIES

Having set the scene for residential lighting in Europe, the report now focuses on the three DELight partner countries: Germany, Sweden and the UK. These countries represent a fair cross-section of Europe on the basis of a number of characteristics which relate to lighting, such as levels of electricity consumption, the structure of the Electricity Supply Industry and the type of lighting installed in the home. However, it is difficult to know the extent to which the countries are actually representative of lighting in Europe, since it is not clear what representative means for lighting. Some of the important characteristics are outlined here to give an indication of how applicable the in-depth studies of these three countries (covered in the next three chapters) are to the rest of Europe.

3.6 HOUSEHOLDS

There are around 64 million households in Germany, Sweden and the UK - representing just over 40% of all households in the EU. Dwellings range in size from an average of 110m^2 in Sweden, to 92m^2 in Germany with those in the UK being the smallest at 84m^2. The three countries are situated in the northern half of Europe, Sweden at the extreme with the longest hours of darkness during winter.

Electricity used in households in these three countries accounts for 45% of residential electricity consumption in the EU, with prices across the countries covering the full range found in the EU (Table 5-1).

Table 5-1 Total residential electricity consumption, Germany, Sweden and UK, 1995/6

	Residential Electricity Consumption (TWh)	Proportion of EU Residential Electricity Consumption	Price of residential electricity (ecu/kWh)
Germany	111.7	21.5%	0.16
Sweden	19.2	3.7%	0.08
UK	101.6	19.6%	0.10
EU	519.0	100%	0.08-0.17

Source: Country pictures (See Chapter 2 of supplementary report)

3.7 ELECTRICITY INDUSTRY

The structure of the Electricity Supply Industry (ESI) in each country is slightly different:

- Germany: The ESI has three levels : nine national utilities, responsible for the majority of electricity generation, 46 regional and about 800 local utilities. Each group accounts for around one third of electricity sales to households.
- Sweden: There are over 300 electricity suppliers in Sweden, with 90% of the total supply concentrated in the seven or eight largest companies.
- The UK: Great Britain has fourteen regional Public Electricity Suppliers, three main generating companies and an independent distribution network. Northern Ireland has a separate organisation. Liberalisation of the gas and electricity markets should be complete by the end of 1998 when each householder will be able to choose to purchase both gas and electricity from a wide range of companies.

The ESI structure and liberalisation of the industry are important factors in terms of motivation for investment in energy efficiency. The EC Directive adopted in 1996 has laid the foundation for liberalisation of the electricity market in all fifteen Member States, with the corresponding directive for the gas market expected to follow in 1998. Liberalisation of the UK ESI began in 1992 and has been used as a model of this process in other countries, such as Sweden where deregulation of the electricity market came into force on 1 January 1996. A major consequence of liberalisation is that introduction of energy efficiency through regulation of utilities is far more difficult. In the UK, the Energy Savings Trust (EST) was set up to perform this role in conjunction with the Office of Electricity Regulation (OFFER). The German ESI is currently in the process of liberalisation, representing a move away from the network of small, local government owned utilities which has encouraged a strong political interest in energy efficiency in the past.

The method of electricity generation also varies between the countries, as shown in Table 5-2. Germany and the UK are similar, with a large percentage of fossil fuel generation, reflected in the high CO_2 emission factors. The German and UK governments have committed to reducing CO_2 emissions by 25% and 20% respectively from 1990 levels by 2010. In contrast, Sweden has a very low proportion of fossil fuel generation, the majority of electricity generated being hydro-electric and nuclear. The political focus in Sweden is to reduce dependence on nuclear power, rather than achieving reductions in CO_2 emissions.

Table 5-2 Electricity generation mix, Germany, Sweden and UK

	Fossil fuels	**Nuclear**	**Hydro-electric**	**Renewable**	**Carbon dioxide emission factors 1997 (kg C/kWh)**
Germany (1993)	66%	29%	3%	2%	0.20
Sweden (1997)	4%	48%	48%	-	0
UK (1995)	71%	27%	1%	1%	0.12

Sources:
Germany: Hessisches Ministerium fuer Umwelt, Energie und Bundesangelegenheiten 1994;
Sweden: EM 1998;
UK: DUKES 1996.

3.8 RESIDENTIAL LIGHTING

3.8.1 Electricity consumption

Average household lighting electricity use in all three countries is similar: 720 kWh per annum in the UK, 760 kWh pa in Sweden and the highest in Germany at 775 kWh pa, representing around 16% of residential electricity consumption in Sweden and the UK and 27% in Germany. These figures are taken from the results of the stock models of lighting consumption undertaken as part of this project (Chapter 8) and can therefore be considered to be reliable estimates. The UK is the only one of the three where actual monitoring of lighting consumption has been undertaken (Electricity Association 1998), confirming the figure of 720 kWh pa and therefore giving greater confidence in the figures. There is currently a study in Sweden measuring hours of lighting usage but the full results are not yet available and in Germany, no monitoring has been conducted to date.

As a proportion of residential peak demand, domestic lighting in the UK represents around 27% (Electricity Association 1998). Peak load for the whole system is around noon in Germany. There is a strong motivation in the UK to reduce residential lighting consumption in order to reduce peak load.

3.8.2 Ownership

German and Swedish households have a higher number of bulbs than the EU average of 24, with an average of 30 and 40 bulbs respectively. Ownership in the UK is lower at 20 bulbs per household. Halogen lighting is very popular in Germany and Sweden, but is not so widespread in the UK. In terms of CFL ownership, Germany has the highest percentage of households with CFLs as well as the highest number of CFLs per household and the cheapest bulbs. Sweden has the lowest level of ownership, although the average number of CFLs per owning household is similar to Germany (Table 5-3).

Table 5-3 CFL ownership and price, Germany, Sweden and UK

	Price of CFLs (ecu)	Percentage of households owning CFLs	Number of CFLs per owning household
Germany	10	50%	4.3
Sweden	13	10%	4.0
UK	15	23%	3.0

Source: Country pictures

The installation of light fixtures in the home and the extent to which they are perceived to be part of the house is different for each country. In the UK the majority of ceiling and wall fixtures are fixed and considered to be part of the house - when people move they will only take their portable fixtures with them. In Germany, the ceiling and wall fixtures are also fixed, but most are taken with people when they move house, along with the portable lights. Installation of fixtures in Sweden is quite different - most ceiling and wall fixtures plug into sockets provided on the walls and ceilings and so cannot be classified as fixed in the same way. The only locations where the fixtures may be wired into the house are the kitchen and bathroom. Apart from these, Swedish householders take all their light fixtures with them when they move.

The differences in the way fixtures are installed indicates the need for some policies to be country-specific. For instance, specifying energy efficient luminaires in the building regulations for new homes would be effective in the UK, but would have little effect in Sweden or Germany. It is not clear which, if any, of these systems represents what is typically found throughout Europe, but the UK appears to be unusual.

The various CFL campaigns that have been undertaken in each country are summarised in Chapter 9.

3.9 DETAILED STUDIES

Three key aspects of lighting were investigated in the detailed studies of the three countries:

1. An on-site survey to identify the type of lighting installed in homes and the extent to which this represents a barrier to installing energy efficient lighting.
2. A telephone survey to establish people's attitudes to CFLs and lighting in general and the resulting barriers that exist.
3. Construction of a lighting stock model estimating lighting electricity consumption and the potential savings available for each country.

The results from each are discussed in the following three chapters.

CHAPTER 6: TECHNICAL CONSTRAINTS

4.1 INTRODUCTION

The use of integral ballast CFLs, rather than modular or dedicated systems, is the most common application of CFLs in the domestic sector, treating them as direct replacements for GLS bulbs. While this approach has the advantage, in theory, of being the quickest way to access the savings and does not require any major changes to the fixtures in the home, it is not ideal. The majority of luminaires in homes across Europe are designed for, and use, GLS bulbs and are therefore not necessarily suitable for use with CFLs. Because of differences between the two technologies, there are a number of factors that need to be taken into account when using CFLs in the existing fixtures, such as orientation of the bulb and light distribution. Most householders will be unaware of these technical issues and, given the present retail structure and lack of informed retail staff, they are unlikely to find out about them. Mis-application of the technology, by using CFLs in inappropriate fixtures, may well have put people off using CFLs in the past because of the resulting poor light quality or shortened bulb life.

Aesthetics are also an important issue, and becoming more so, both in terms of the appearance of the bulb in the fixture and the suitability of the light output - CFLs are not appropriate in all locations, for instance where accent lighting is desired, which is better provided by halogens. Hence, the successful application of integral ballast CFLs is dependent on identifying the right type of CFL to use in a particular fixture, ensuring good performance of the bulb and satisfaction of the householder.

There is currently a wide range of different sizes and shapes of CFLs available on the market. While, on the one hand, this means it should be easier to find the right type of bulb to suit a certain fixture, it can also be confusing for the householder. Another consequence of the constant appearance of new products on the market is the lack of confidence this generates in the stability of the technology. If people are unsure of new technologies, they tend to keep to well-tried solutions which have worked in the past, although these may not be ideal (Wood-Robinson 1983).

The lack of suitable fixtures is often quoted by householders as a reason for not installing integral ballast CFLs. The extent to which this is true, in terms of physical fit, aesthetics and bulb performance, was investigated through a detailed survey in the three partner countries. Suitability was judged from both a technical point of view, by a lighting expert, and from the householder’s point of view, in terms of what they would be happy using in their home. The results from the survey indicate how far the existing luminaires actually represent a barrier to energy efficient lighting, as well as highlighting areas where fixture designs could be improved. Further details on the survey design and analysis of the results are included in Chapters 4 and 7 of the Supporting Material and in Palmer and Suvilehto (1997) and Persson (1997).

4.2 METHODOLOGY

On-site surveys were carried out in 24 households in each of the three countries during July and August 1997. Due to the in-depth nature of these surveys, it was not possible to use a larger sample. The households were selected by the surveyor in each country and located in Kiel (Germany), Halmstad (Sweden) and Gloucestershire (UK). The surveyors aimed to achieve a cross-section of households in terms of age (of the householders), accommodation type (flat or house) and location (rural, village and town). Even though this does not constitute a representative sample, the information collected provides a useful and informative starting point for looking at the role of the fixture in determining the potential for energy savings and also allows an initial comparison of this potential and of the lighting installed in the different countries.

The key pieces of information collected from each household were:

1. a detailed inventory of all luminaires in the house, both internal and external, classified by type of fixture, the bulb(s) it held and if it was the 'primary' fixture (ie the most used) for that particular room;
2. the suitability for CFLs of those fixtures designed for GLS bulbs in terms of what was acceptable to the surveyor (the 'technical potential') and to the householder (the 'acceptable potential'), independent of the surveyor's opinion;
3. the type of light the householders use for various tasks and the householders' attitudes to CFLs, based on questions taken from the cultural survey - another part of the DELight project (see Chapter 7).

Five categories were used to classify suitability of the luminaires for integral ballast CFLs:

1. **CFL will not physically fit**: the structure of the fixture would not allow replacement of the GLS bulb with a CFL (Figures 6-1 and 6-2). Installation of a CFL would require a new fixture.
2. **Unacceptable colour rendering**: the CFL fits into the fixture, but the colour rendering was inappropriate for the particular location of that luminaire. This could be corrected through a new fixture.
3. **Poor light distribution**: the CFL fits into the fixture, but the light distribution is unacceptable. Again, this could be corrected through a new shade or fixture.
4. **CFL protrudes from the shade**: the CFL fits into the fixture but is too long and protrudes from the shade (Figures 6-3 and 6-4). This could be corrected by a new shade.
5. **Successful conversion**: direct replacement with a CFL is possible with acceptable appearance, light distribution and quality (Figures 6-5 to 6-8).

There was also a further category of those luminaires which were not considered for conversion, classified as 'conversion not attempted'. This includes fixtures installed with fluorescent strips or tungsten halogen bulbs, any CFL dedicated fixtures and those fixtures on dimmer switches.

Because the surveys were carried out during the summer months, it was only possible to gauge opinion on the performance of the bulbs in daylight. Therefore, the issue of light quality could not be fully investigated in the survey. This is of more relevance to the acceptable potential, since the surveyors would have been aware of such issues when assessing suitability. Quality of light was investigated in more detail in the cultural survey (Chapter 7).

For simplicity, categories 1 to 4 have been amalgamated in the following analysis to give three main classes: 'successful conversion', 'for future conversion' (categories 1 to 4 combined) and 'conversion not attempted'.

4.3 KEY RESULTS

4.3.1 Type of lighting installed

Incandescent bulbs were the dominant light source in all the households surveyed, GLS bulbs being used in 79-81% of luminaires (Table 6-1). In the German and Swedish households, a greater proportion of luminaires were installed with halogen bulbs than with CFLs. Ownership of CFLs was highest in the UK sample: with those households that owned them having an average of three, consistent with the national picture. CFL ownership was lower than the national average in the Swedish and German samples, at two and three CFLs per owning household respectively. Multiple bulb luminaires were common in the German and Swedish households whereas in the UK, most luminaires were single bulb. The use of 'Christmas tree lights' (strings of twenty-five to forty 2W bulbs) in several of the German households means that the average number of light bulbs may be slightly high. Since it is not known what is representative, the extent to which these households reflect typical lighting in the three countries is unclear.

Table 4-1 Information on surveyed households: technical survey in Germany, Sweden and UK

		Germany	Sweden	UK
Household information	number of households	24	24	24
	number of rooms per household	3.8	3.9	4.5
Light bulbs	number per household	36	45	21
	average installed wattage (W)	1438	1539	1231
	average wattage per bulb	40	34	59
Light fixtures	average number per household	21	30	20
% with incandescent bulbs	GLS	79	80	81
	tungsten halogen	8	6	5
% with fluorescent bulbs	fluorescent strips	7	11	3
	CFLs	6	3	11

Note:
Number of rooms excludes kitchens and bathrooms, but bulbs and fixtures in these rooms are included
These figures are from the 72 households surveyed and may not be nationally representative

The UK households had the lowest number of bulbs with the highest average wattage per bulb, whereas Sweden had the highest number of bulbs but with the lowest average wattage. Dimmer switches were most popular in Swedish households, being used with 7% of luminaires compared to 4% in Germany and 5% in the UK. These represent a further barrier to CFLs at present. Differences in the style of lighting are also reflected in the range of fixtures found in the households (Table 6-2).The UK households have a high percentage of ceiling fixtures whereas the German and Swedish households have a greater proportion of wall and free-standing luminaires.

Table 4-2 Types of fixtures installed in the surveyed households: technical survey in Germany, Sweden and UK

	Germany	Sweden	UK
Ceiling pendant	15%	9%	37%
Ceiling surface/recessed	24%	22%	23%
Wall mounted	26%	28%	18%
Floor-standing	10%	5%	4%
Table and desk luminaire	21%	23%	18%
Other	4%	13%	0%

Base: 24 households in each country

In terms of fixed and portable fixtures, 78% of the UK luminaires were fixed, 65% in Germany and only around 11% in Sweden. It is important to note that fixed fixtures in the UK and Sweden are left behind when people move house, whereas almost all fixtures, both portable and fixed, move with the householder in Germany.

4.3.2 Potential for CFLs

The potential identified in this survey is in terms of the opportunities for installation of integral ballast CFLs into the existing fixtures in the home. A full list of the CFLs used in the surveys is included in Chapter 4 of the Supporting Material. Across the three countries, the surveyors found 32-42% of all luminaires suitable for CFLs, without any modification necessary (Table 6-3). The percentages appear lower for Sweden and

Germany because of the high proportion of luminaires that were not considered for conversion, due to the popularity of halogen bulbs and dimmer switches in these households.

Table 4-3 Technical and acceptable potential for CFLs: technical survey in Germany, Sweden and UK

	Technical potential			Acceptable potential		
	Germany	**Sweden**	**UK**	**Germany**	**Sweden**	**UK**
Successful conversion	34%	32%	42%	32%	31%	46%
For future conversion	47%	43%	50%	49%	44%	46%
Conversion not attempted	19%	25%	8%	-	-	-

Base: 24 households in each country - percentages of all fixtures

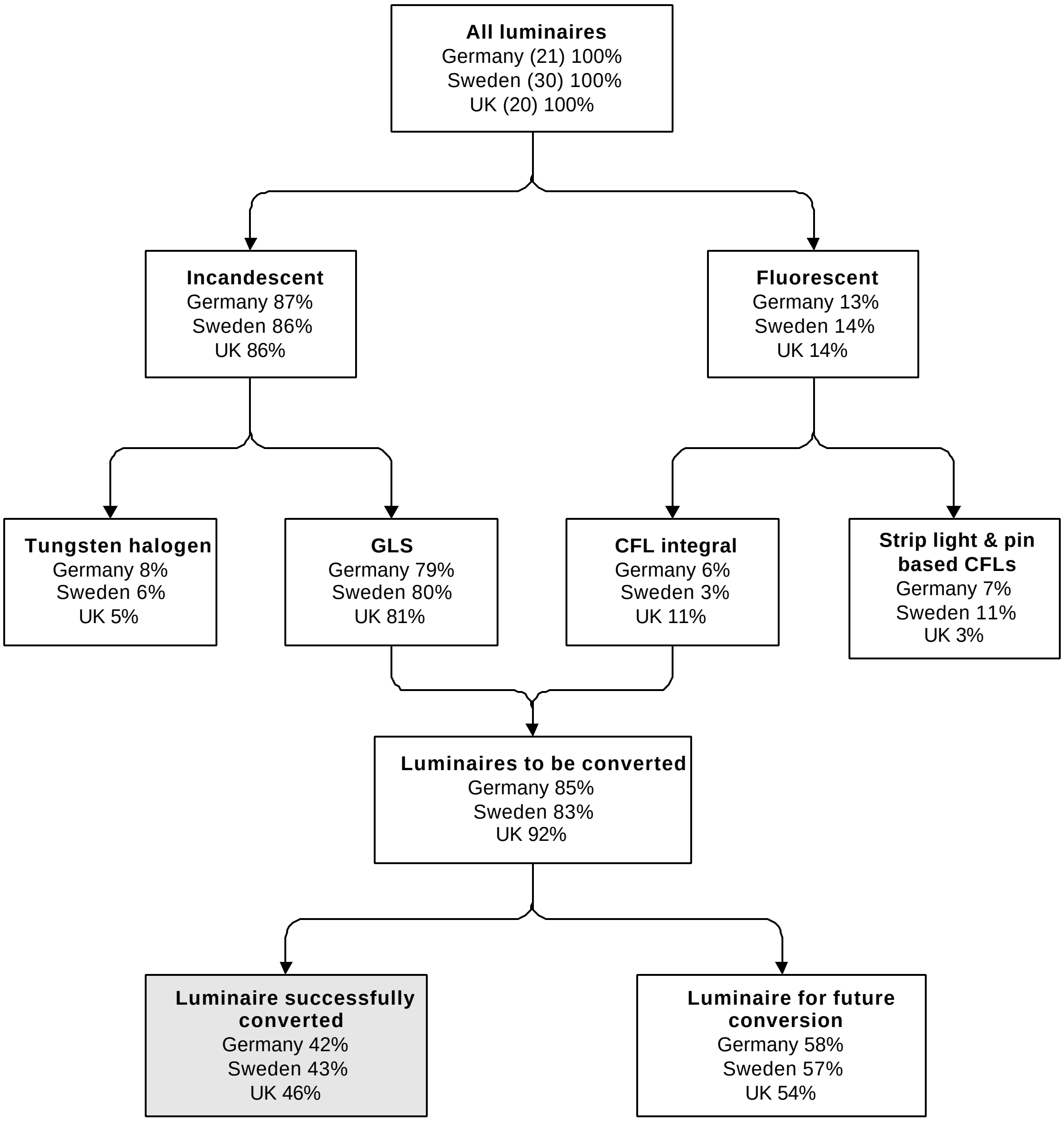
There is good agreement between the technical and acceptable potentials in all three countries, with the UK households apparently more willing to accept CFLs in fixtures considered unsuitable by the surveyor than in Germany and Sweden. Although the householders' opinions will have been influenced to a certain extent by taking part in the survey, the acceptable potential illustrates that it is possible to use CFLs in the existing fixtures to the satisfaction of the householder. This may not, of course, represent what they will actually do in practice. Many of the householders were surprised at the range of CFLs used in the survey, which was far greater than found in most retail outlets, and felt it to be confusing. However, they did have the opportunity to try out the various types in their own fixtures, making it easier to identify the right one to use. This highlights the benefit of expert advice and demonstrations in encouraging the appropriate use of CFLs.

Since the focus is on installing integral ballast CFLs in luminaires designed for GLS bulbs, it is useful to look at the 'technical potential' in terms of these fixtures (ie excluding those in the 'conversion not attempted' category). This gives a similar proportion of luminaires suitable for immediate conversion in each country, ranging from 42-46% (Figure 6-9).

Assuming one bulb per luminaire as a minimum, the 'successful conversion' category indicates that, in each household, at least seven bulbs in Germany, nine bulbs in Sweden and eight bulbs in the UK could be changed to CFLs immediately.

These potentials are conservative estimates. Given current trends towards smaller CFLs and CFLs made to look like traditional incandescent bulbs, the number of existing luminaires that could be considered to be successful conversions will increase in the future. Also, by simply replacing the shade, requiring minimal investment on the part of the householder, the 'successful conversion' category could be almost doubled in Germany and the UK.

However, the 'successful conversion' category will never reach 100% of luminaires since there will always be some fixtures where CFLs are not appropriate, either for technical, economic or aesthetic reasons. Such locations represent an opportunity for other energy-efficient light sources to replace GLS bulbs, such as the IEA 'future bulb'.



Note: These figures are from the 72 households surveyed and may not be nationally representative

Figure 4-9 Technical potential for installing CFLs into the existing fixtures: technical survey in Germany, Sweden and the UK

4.3.3 Fixture types suitable for conversion

Some luminaire types were more suited to the installation of CFLs than others. A breakdown of 'successful conversion' category in terms of the different fixture types is shown in Figure 6-10. This is helpful in guiding the householder to which fixtures are most appropriate for CFLs. Ceiling pendant fixtures were particularly suitable for conversion in the UK (Figures 6-5 and 6-6), while ceiling surface and recessed luminaires were more successful in Sweden. In luminaires where the bulb was visible, globe CFLs were effective and often represented an improvement on GLS bulbs because glare was reduced (Figure 6-7). Cooker hoods were identified as being good conversions for CFLs in terms of physical fit, but low levels of usage and high temperature may mean that such locations are unsuitable.

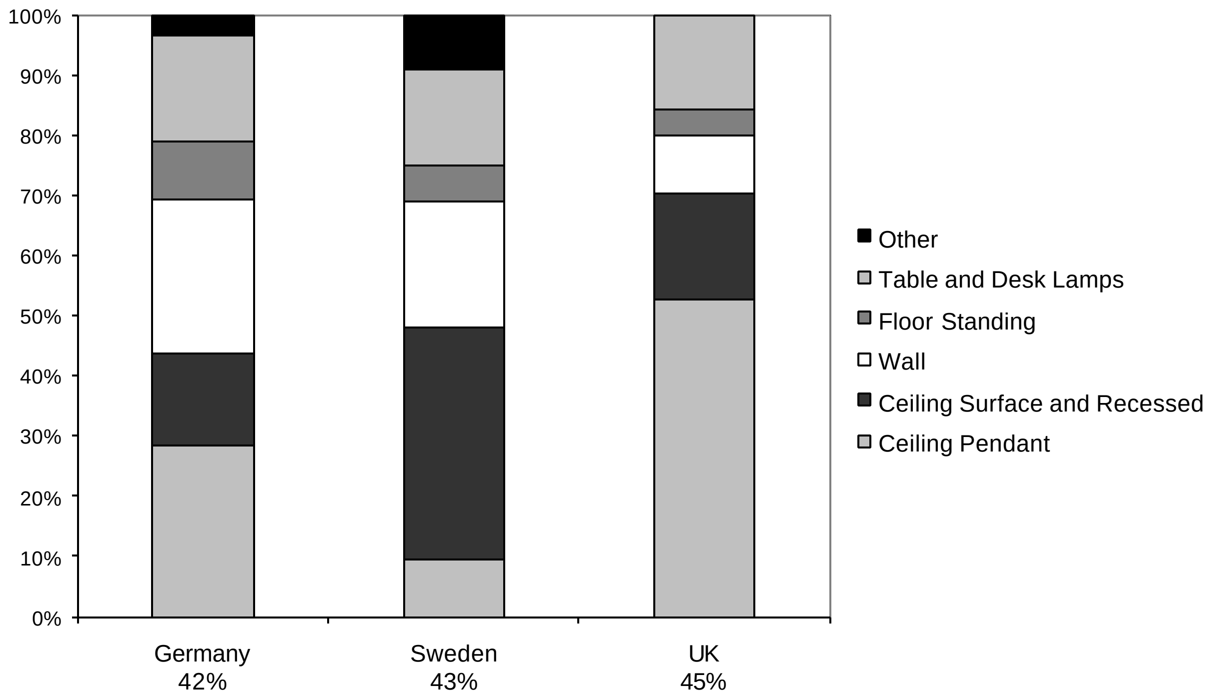


Figure 4-10 Proportion of fixture types within the successful conversion category: technical survey in Germany, Sweden and UK

The fixture types that were classified as being for future conversion represent an opportunity for appropriate dedicated fixture designs. As illustrated in Figure 6-11, the existing wall fixtures and table and desk lamps made up a large proportion of this category in all three countries.

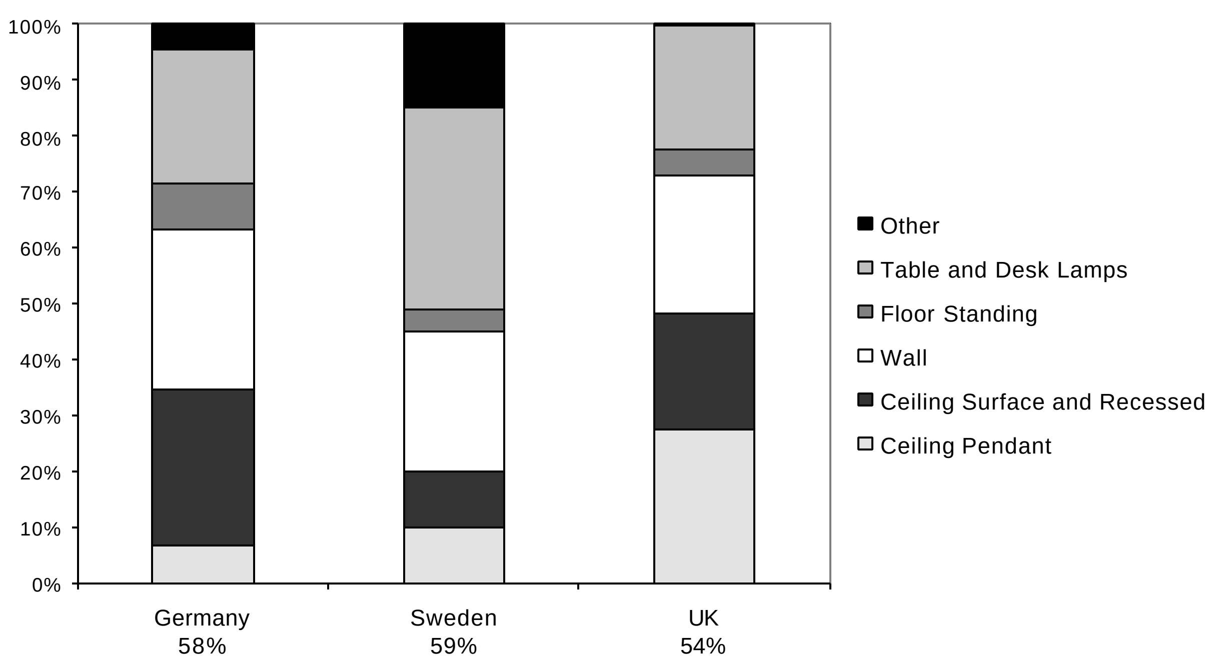


Figure 4-11 Proportion of fixture types considered unsuccessful conversions: technical survey in Germany, Sweden and UK

6.3.4 Cost-effectiveness of conversions

Not all the successful conversions identified offer a rapid pay back to the householder. Identification of the primary luminaire for each room gives an indication of relative usage levels and therefore the cost-effectiveness of these conversions. The actual hours of use of primary luminaires will vary depending on the room they are in (for instance, the primary luminaire in the bedroom is likely to be used less than the one in the living room), and who within the household defined them. Of the luminaires in the ‘successful conversion’ category, 66% in Germany, 50% in Sweden and 74% in the UK were also classified as primary fixtures. Therefore, the majority of successful conversions are the most cost-effective for a particular room and offer the fastest pay back in high use locations such as living rooms and hallways.

A study by DEFU established that it was cost-effective to install eleven CFLs, on the basis that these bulbs were used for more than two hours a day, in households in Denmark, Germany and the Netherlands, (DEFU 1996). Six CFLs was assumed to be a more realistic estimate for immediate installation, since some of the eleven fixtures would need modification and the householder may not accept all of them. The results from the technical survey have confirmed that some of these could be installed immediately, given the constraints of the fixtures. However, a number of high use fixtures will require modification before the full savings estimated by DEFU can be achieved, since not all fixtures identified as suitable will be in use for over two hours a day.

6.3.5 Electricity savings

The electricity savings indicated by the potentials were calculated for the primary fixtures in the four highest used locations (for more details, see Chapter 7 of the Supporting Material). Usage figures were available from other studies conducted in Sweden and the UK: a Swedish project, run by the utilities of Borlänge and Upsalla, measuring hours of lighting use and a survey of householders’ estimates of lighting usage in the UK (Electricity Association pers comm 1997). No such data were available for Germany and so hours of usage were estimated by the surveyor. The following were identified as the highest used areas:

- halls, main living room, kitchens and external in Germany;
- halls, landing, main living room and external in Sweden;
- halls, landings, kitchens and main living room in the UK.

Installing one CFL in the primary fixtures in each of these four locations could achieve savings of around 200 kWh per household (Figure 6-12), assuming an average daily usage of 3.5 hours per bulb. This would be to the complete satisfaction of the householder, provide a good light (by professional standards) and require no expenditure on the fixture. It would, therefore, be at least the same level of service as the present bulbs. Because these are high use fixtures, the expenditure would be cost effective and the savings would repay the additional price of four or five bulbs in under three years.

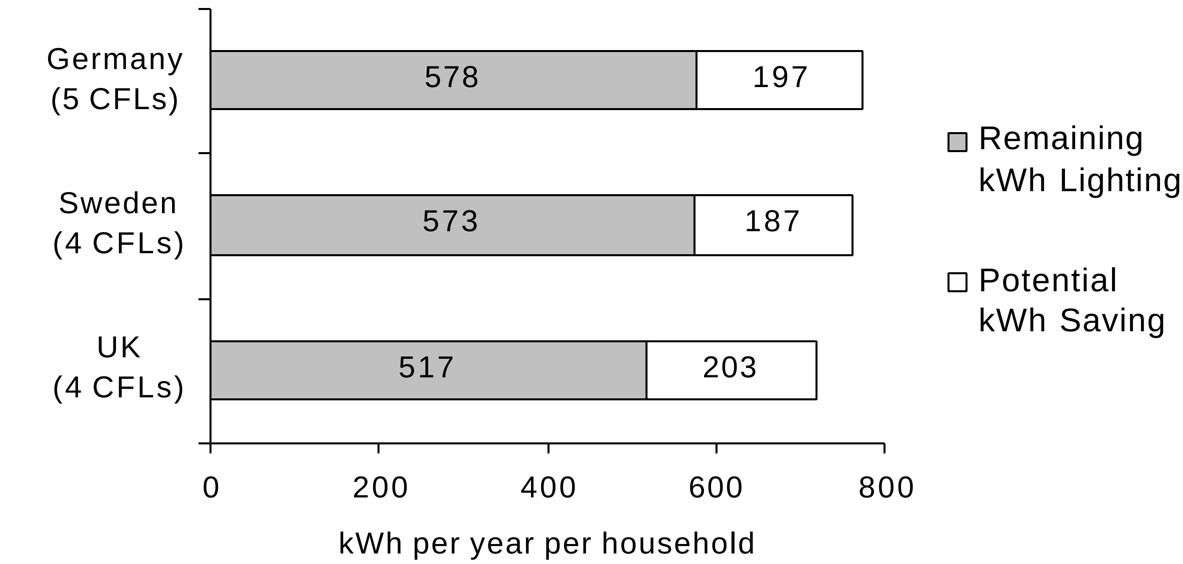


Figure 4-12 Electricity savings from installing CFLs in fixtures in the four highest used locations: technical survey in Germany, Sweden and UK

6.3.6 Location of CFLs in practice

Since a number of the surveyed households already used CFLs, it is possible to identify where they had installed these bulbs prior to taking part in the survey (Table 6-4). Across the three countries, the majority of these CFLs were installed in the high use locations. The living room was the most popular place for CFLs in Germany and the UK, whereas they were more likely to be used in the kitchen or for external lighting in Sweden.

Table 4-4 Location of installed CFLs: technical survey in Germany, Sweden and UK

	Germany	Sweden	UK
Main living room	28%	9%	22%
External	17%	35%	9%
Kitchen	10%	30%	7%
Hall	10%	0%	16%
Total	65%	74%	54%

Base: CFL owners in each country

However, in Sweden, only 43% of these were primary fixtures, compared to 76% in Germany and 84% in the UK. This indicates that it may be more difficult for Swedish householders to install CFLs in locations which are most cost effective.

4.4 CONCLUSIONS

In the 72 houses surveyed, around 80% of fixtures currently use an incandescent bulb. There was a larger proportion of halogen bulbs installed compared to CFLs in both Germany and Sweden. This distribution of ownership is confirmed by national sales data used in the stock model of lighting electricity consumption (Chapter 8). There is greater similarity in the type of lighting installed in the German and Swedish homes than in the UK. The UK households are different in terms of both the number and type of bulbs installed as well as the style of fixtures and the way in which they are wired into the house. These households had a high proportion of fixed ceiling luminaires, with the majority of fixtures using a single high wattage bulb. Whilst this gives greater savings per bulb (for example, a 20W CFL replacing a 60W GLS bulb in the UK, compared with a 9W CFL replacing a 25W GLS bulb in Sweden), the use of multiple bulb luminaires in Germany and Sweden means relatively larger savings per fixture than in the UK.

In all three countries, the potential for the installation of integral ballast CFLs is similar at 42-46% of existing incandescent luminaires. This represents what could be done immediately and is acceptable to the householder, requiring no further investment other than the purchase of the bulb. The majority of these CFLs would go into the highest used fixture in a room. This is a conservative estimate given the possibilities of smaller CFLs in the future and the marginal cost of changing some shades. In order to achieve this potential, it is likely that people will need guidance on how to identify which of their fixtures are suitable and how to choose the appropriate type of CFL. There are also further savings available through the application of other technologies, such as the IEA ‘future bulb’, where the use of CFLs is inappropriate.

This approach provides an indicative national figure, irrespective of the bias in the small samples. The figure of 46% of incandescent fixtures in the home being suitable for CFLs can, therefore, be used with sufficient confidence. These results form the basis of the FITP (Fixtures and Immediate Technical Potential) scenario described in Chapter 8, illustrating the maximum level of savings the conversions could achieve when extrapolated to the whole country.

Since a large proportion of the existing fixtures are suitable for use with CFLs, there is no need to look at the economics of changing fixtures in the short-term. There are already ample, cost-effective opportunities available that are acceptable to the householder. The immediate savings of 200 kWh represent over a quarter of lighting electricity used of a typical household (720-775 kWh) in the three countries. In the longer term, the survey indicates the types of fixtures which are currently unsuitable for CFLs and may therefore be an appropriate target for any programme focusing on the design of CFL dedicated fixtures.

CHAPTER 7: CULTURAL ISSUES

The success of CFLs depends upon the technology satisfying the requirements people have for lighting in their homes. It is therefore important to establish what these requirements are. Lighting is not just something to see by - it is important in creating an atmosphere in the home. The type of light that people want in their hallway will be different to the lighting they may choose for the living room or the kitchen. Such requirements will also vary between countries; Wilhite *et al* (1995) demonstrated differences in attitudes to lighting between countries, with a corresponding impact on energy use. An understanding of how people's lighting requirements vary between rooms and between countries can help to identify suitable energy efficient lighting systems, using the appropriate combination of CFLs and fixtures.

People also have to believe that CFLs can satisfy their lighting requirements. Around 70% of households in the EU do not currently own a CFL. Price is frequently given as the main reason for this, although people are also unsure about the performance and light quality of the bulbs. However, many of these concerns are no longer justified with today's technology. Some of the misconceptions about CFLs have arisen because fluorescent lighting has (in Europe at least) associations with lighting in the workplace, and an image of giving a strong, harsh light. Bad experiences with CFLs in the past, either as a result of using the inferior early technologies, or because of the use of CFLs in inappropriate fixtures and locations, have also played a part in generating myths about CFLs. Such misconceptions seem to be preventing people from installing their first CFL. Once this first step has been taken, the average household goes on to buy another two or three CFLs, indicating that experiencing the technology can help overcome some of these misconceptions. Countries will differ in terms of the perceptions and experience of CFLs, as well as people's motives for buying them. Factors such as the year of introduction of CFLs onto the market and the number and type of CFL campaigns there have been to date, in addition to any cultural influences, will also have an effect.

The technical survey, discussed in the last chapter, demonstrated that the fixtures in the house are not necessarily the major barrier they are often thought to be. A second survey was conducted to investigate the extent to which other views held about CFLs are true in practice. By comparing opinions on CFLs held by owners and non-owners, it is possible to identify how perceptions of CFLs differ between these two groups. This survey also focused on the type of light people actually want in their homes and to establish how this fits with their current perceptions of CFLs and therefore identify the most suitable locations for these bulbs. In combination with the technical survey, it is possible to identify if suitable fixtures are actually found in these locations. In addition to the three partner countries, Spain was also included in this survey, enabling cross-country comparisons of attitudes to lighting and CFLs between both Northern and Southern European countries. Further details on the analysis of the results can be found in Chapters 6 and 7 of the Supporting Material.

4.5 SURVEY METHODOLOGY

A telephone survey was undertaken during July 1997 by the Fine Fieldwork Company on a randomly selected sample of at least 150 people in each of four countries: Germany, Sweden, the UK and Spain. Whilst there was a bias in the sample towards people that own a telephone, quotas for age, sex and socio-economic group were fulfilled to ensure that the sample was nationally representative for these criteria. Despite this, figures for CFL ownership and awareness were somewhat higher than the national average, although it is not clear why this should be (Table 7-1).

Table 7-1 CFL ownership and awareness: cultural survey in Germany, Sweden, UK and Spain

	Germany	Sweden	UK	Spain
CFL awareness (%)	93	67	79	78
Households with CFLs (%)	51	32	27	27
Average no. CFLs per household	2.2	1.4	0.7	1
CFLs per owning household	4.3	4.5	2.6	3.8
Number of households	150	152	157	150

The interviews were conducted by native speakers from each country and covered the following key areas (a copy of the questionnaire is included in Chapter 6 of the Supporting Material):

- The type of lighting preferred for selected household activities
- Main reasons for having or not having CFLs
- Opinions and knowledge of CFLs

Respondents were asked to select an adjective that described the type of light they wanted for the following activities: cooking, watching TV, eating, dressing, reading, receiving visitors, relaxing and listening to music, using hallways and stairs, and young children's activities. They were asked to give both a first and second choice of adjective.

The key adjectives used to describe lighting were difficult to identify. Country differences became apparent when designing the questionnaire - some adjectives did not translate into words that would be used to describe lighting in other languages. Other adjectives were considered to have negative connotations with regards to lighting in one language whereas it was a positive description in another language. Five adjectives were chosen to given a range of options for each country (Table 7-2).

Table 7-2 Translations of adjectives: cultural survey in Germany, Sweden, UK and Spain

Germany	Sweden	UK	Spain
Klar	Klar	Clear	Clara
Weich	Mjuk	Soft	Suave
Natürlich	Natrulig	Natural	Natural
Hell	Skarp	Bright	Brillante
Behaglich	Mysig	Cosy	Acogedora

The questionnaire was also completed by the 72 householders in the technical survey, giving a detailed insight into the extent to which people's perceptions of light match up to what they actually have installed in their homes. A comparison between the two surveys can also help identify how the potential identified in the technical survey to install CFLs in 42-46% of the existing fixtures might be accessed.

4.6 WHAT DO PEOPLE WANT FROM THEIR LIGHTS?

For each of the four countries, the majority of responses for all activities were dominated by two adjectives:

- Germany: bright and cosy
- Sweden: clear and soft
- UK: bright and soft
- Spain: clear and soft

'Natural' did not feature as an important quality of light as the first choice in any of the countries, although it was the strong second choice in most countries for eating, dressing and children's activities. Allowing for the different interpretations of the words in the various languages and for ease of analysis, the adjectives can be considered to fall into three distinct groups: clear/bright, soft/cosy and natural.

Among the countries, particularly Germany, Sweden and the UK, there was a large degree of similarity in the adjectives chosen for each activity (Table 7-3). On the whole, Spanish householders showed a greater preference for bright/clear light, possibly reflecting the sunnier climate in Southern Europe. There was a significant difference in the type of light preferred when entertaining visitors and eating: the Spanish choosing bright/clear light rather than soft/cosy light as in the other three countries.

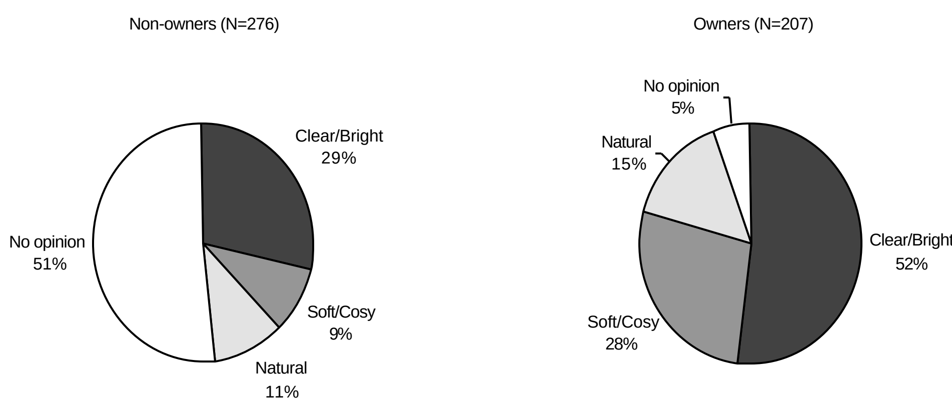
Table 7-3 Most common lighting requirements for selected activities: cultural survey in Germany, Sweden, UK and Spain

Activity	Germany	Sweden	UK	Spain
Cooking	Bright/Clear	Bright/Clear	Bright/Clear	Bright/Clear
Dressing	Bright/Clear	Bright/Clear	Bright/Clear	Bright/Clear
Reading	Bright/Clear	Bright/Clear	Bright/Clear	Bright/Clear
Using Hallways/Stairs	Bright/Clear	Bright/Clear	Bright/Clear	Bright/Clear
Children's Activities	Bright/Clear	Bright/Clear	Bright/Clear	Bright/Clear
Eating	Soft/Cosy	Soft/Cosy	Soft/Cosy	Bright/Clear
Receiving Visitors	Soft/Cosy	Soft/Cosy	Soft/Cosy	Bright/Clear
Relaxing	Soft/Cosy	Soft/Cosy	Soft/Cosy	Soft/Cosy
Watching TV	Soft/Cosy	Soft/Cosy	Soft/Cosy	Soft/Cosy

Base: 609 surveyed households

4.7 HOW DO PEOPLE PERCEIVE CFLS?

Just under 80% of all households surveyed were aware of CFLs, 57% of these being non-owners. These respondents (both owners and non-owners) were asked to rate the quality of light from a CFL in terms of the same adjectives (Figure 7-1). Over half of these non-owners had no opinion, while the majority of those who did considered the light to be 'clear/bright'. Spain was the only country in which 'natural' light was the dominant choice among non-owners (16%) and also had the highest proportion of non-owners who did not express an opinion (66%).

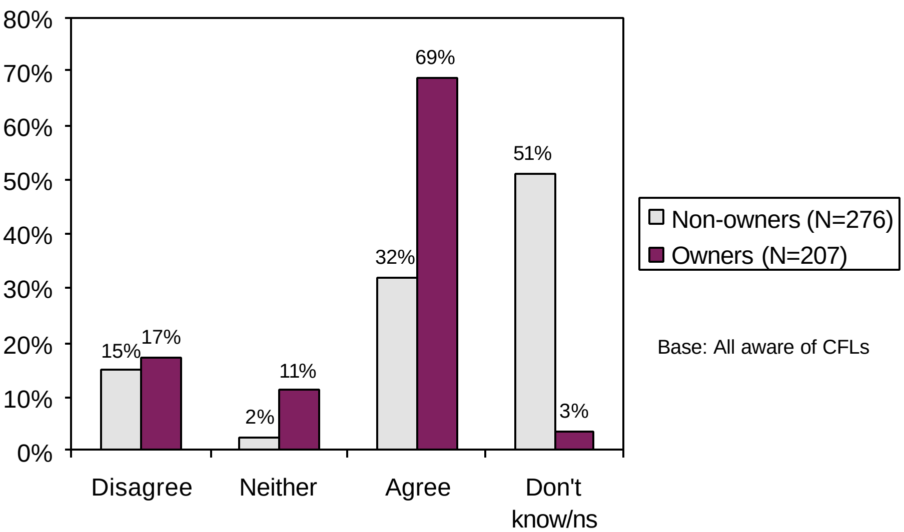


Base: all aware of CFLs (N=483)

Figure 7-1 Perceptions of light produced by CFLs among CFL owners and non-owners (all countries): cultural survey in Germany, Sweden, UK and Spain

Among owners, the majority did express an opinion, with ‘clear/bright’ light also being the most popular choice. Relatively more owners than non-owners considered the light from CFLs to be ‘soft/cosy’, while the proportion viewing the light as ‘natural’ was similar in both groups. In the UK, ‘soft/cosy’ was actually the most popular description of CFLs among owners (43%), while in German and Sweden, ‘clear/bright’ was dominant (65% and 66%). In contrast to the other three countries, opinions were evenly distributed between the three groups of adjectives among owners in Spain.

A large shift in opinion between owners and non-owners was also demonstrated in responses to the statement ‘CFLs provide a good light for all my activities’ (Figure 7-2). More than two-thirds of owners agree with this statement, over double the number of non-owners. Spain had both the largest percentage of non-owners who did not express an opinion (62%) and the greatest proportion of owners who agreed with the statement (83%). Negative views were strongest in Germany where 28% of non-owners and 22% of owners did not think CFLs provide a good light for all activities.



Base: all aware of CFLs

Figure 7-2 Responses to the statement 'CFLs provide a good light for all my activities' (all countries): cultural survey in Germany, Sweden, UK and Spain

Of the 34% of households that owned CFLs, between 79% and 90% were satisfied with them (based on how likely they would be to recommend CFLs to a friend or neighbour). Therefore, the majority of owners are happy with their CFLs, viewing them as a flexible light source, with a wide range of opinions expressed about the quality of light provided by these bulbs. A small proportion of people who used CFLs were not prepared to recommend their use to others, indicating that they were not entirely happy with them. Among non-owners there is a lack of knowledge about what a CFL can provide, even though around 70% of all non-owners in the survey were aware of CFLs. Hence it appears that it is ignorance of the technology rather than dislike of CFLs that is the reason for many households not owning CFLs.

4.8 WHY DO PEOPLE HAVE CFLS?

In order to encourage the wider use of CFLs, it is necessary to have some understanding of the perceived advantages and disadvantages of the technology. Opinions from owners, who have experience of CFLs, indicate real benefits to be gained from the use of CFLs, which non-owners may be unaware of. Establishing the reasons why people do not have CFLs indicates obstacles that need to be overcome to encourage ownership. Further comparison of views held on CFLs by owners and non-owners can identify where the mis-conceptions lie and which barriers are actually realised in practice by owners, therefore preventing further uptake of CFLs.

Two open-ended questions were asked to establish the attractions of CFLs and the perceived obstacles to their adoption:

- ‘What would you say are the main reasons for you having CFL bulbs?’ - asked only of owners (Table 7-4).
- ‘What would you say are the main reasons for you not using CFL bulbs?’ - asked of non-owners (Table 7-5).

At least half the respondents in each of the four countries judged financial savings, either in general or as an aspect of reduced electricity use, to be the main benefit of using CFLs. Longer lifetime is also considered to be an important attribute of CFLs by owners in all four countries. Environmental motives were stronger in Germany than the other countries, not featuring in any of the responses from Spain. Only the Spanish positively choose CFLs for the quality of the light. Differences between the countries indicate the need for careful targeting of any programme designed to encourage the uptake of CFLs.

Table 7-4 Main reasons for obtaining a CFL among owners: cultural survey in Germany, Sweden, UK and Spain

	Germany (N=76)	Sweden (N=49)	UK (N=42)	Spain (N=40)
I like the quality of light	-	-	-	40%
Electricity saving (money)	66%	53%	33%	33%
Because they last longer	24%	31%	31%	20%
Money saving general	47%	24%	36%	15%
Electricity saving (environment)	42%	12%	17%	-

Base: CFL owners (N=207)

Note: more than one answer could be given

Respondents who were aware of CFLs but did not own any were asked their main reasons for not using them. The main barrier was felt to be price in all four countries, while in Sweden, Spain and the UK many respondents had not actually considered buying them. Around one in three householders in Spain responded that they were happy with their current lighting and so there is little incentive to try out a new, unknown technology. The Germans gave the greatest range of reasons, largely concerned with aesthetic aspects of CFLs, such as the appearance or light from CFLs. These negative views may have arisen through the inappropriate application of CFLs in the past or through experience of older technology, such as the larger magnetic ballast CFLs, or low quality imports. People may not realise that more modern technology is now available.

Table 7-5 Main reasons for not using a CFL among non-owners: cultural survey in Germany, Sweden, UK and Spain

Reason	Germany (N=64)	Sweden (N=53)	UK (N=82)	Spain (N=77)
Too expensive	31%	48%	33%	34%
Never considered purchase	-	29%	30%	16%
Do not like the light from CFLs	22%	-	-	-
Unattractive	31%	-	-	-
Take too long to come on	9%	-	-	-
Not compatible with light fittings	19%	-	-	-
Happy with current lighting	-	-	-	29%
Don’t know/not stated	8%	13%	10%	1%

Base: non-owners aware of CFLs (N=276)
Note: more than one answer could be given

Therefore, in Sweden, the UK and Spain it is not dislike of CFLs that is preventing people using them. Greater awareness of the advantages and flexibility of CFLs, as judged by owners, could be effective in persuading these people to try out their first CFL in order that they may experience the benefits themselves. In Germany, this may prove to be more difficult since there is a generally negative perception of CFLs among non-owners.

Comparing the responses of owners and non-owners to a series of statements regarding CFLs indicates the opportunities that exist to encourage non-owners to use CFLs and the extent to which views held by non-owners are borne out in practice among owners (Table 7-6). While there is general agreement between owners and non-owners on the majority of statements, the high proportion of non-owners in the ‘don’t know’ category further highlights their lack of knowledge and experience of CFLs.

Most non-owners were unaware of the benefits of CFLs. There was most uncertainty among both owners and non-owners about how long CFLs last in practice, with the majority of non-owners also unsure if CFLs save money in the long run. An equal proportion of owners and non-owners actually disagreed with this statement. These responses imply a lack of confidence in the technology. The convenience of CFLs was recognised by owners and non-owners, with both groups agreeing strongly. Fewer respondents, particularly non-owners, were aware that a major advantage of CFLs is that they get less hot. The environmental benefits of CFLs were recognised by a high percentage of respondents, although, again, the majority of non-owners did not have an opinion on this.

Around one in ten owners and non-owners felt that they are restricted in their choice of light bulbs, while owners are more likely to feel they are expected to buy CFLs, possibly perceiving themselves as ‘green consumers’. A fair proportion of owners and non-owners considered CFLs to be unattractive which may, therefore, be preventing their wider use, particularly in fixtures where the bulb is visible. While this could be tackled through improved bulb design, dedicated fixtures may be a better solution. Most owners considered CFLs to provide a good light for all their activities but were also aware that they are not suitable for all their fixtures. This identifies the fixture, not the bulb, as the perceived constraint, and further emphasises the need for dedicated fixtures.

Table 7-6 Summary of responses to statements about CFLs (all countries): cultural survey in Germany, Sweden, UK and Spain

	Owners			Non-Owners		
	Disagree	Agree	Don't know	Disagree	Agree	Don't know
I don't have any choice over the type of bulbs I buy	83%	12%	3%	53%	3%	33%
CFLs are convenient/don't have to be changed often	7%	87%	5%	0%	52%	43%
CFLs provide good light for all my activities	17%	69%	3%	15%	32%	51%
CFLs don't last as long as they say	58%	12%	28%	18%	8%	69%
CFLs don't save money in the long run	65%	12%	17%	29%	13%	55%
CFLs are environmentally friendly	4%	74%	18%	2%	46%	51%
CFLs have an attractive appearance	41%	42%	3%	28%	25%	42%
My friends think I should buy CFLs	17%	38%	31%	22%	14%	58%
CFLs protect the light fittings (less hot)	5%	67%	25%	4%	32%	60%
CFLs are not suitable for all my light fittings	26%	58%	12%	17%	31%	50%

Base: all aware of CFLs (N=483)

4.9 LINKING WITH THE TECHNICAL SURVEY

The interaction between the bulb and the fixture is crucial in determining the quality of light provided. If CFLs are to provide the type of light people want for various tasks, as identified in the cultural survey, they require appropriate fixtures. The technical survey found the majority of existing fixtures in the home to be unsuitable for CFLs. These fixture types would therefore be an appropriate target for dedicated fixtures, designed to provide the desired quality of light for particular locations. For instance, a high proportion of wall fixtures, often in high usage areas such as the living room, were unsuccessful conversions in all three countries. These therefore represent a good opportunity for dedicated fixtures providing a soft/cosy light.

Results from the cultural and technical surveys demonstrate that one of the main barriers to the adoption of CFLs is the lack of experience and knowledge, rather than any particular dislike or suspicion of them. A better understanding of how a CFL and fixture interact are needed to enable more people to use them appropriately. The cultural survey demonstrated that owners are satisfied with the CFLs they own and view them as a flexible light source, suitable for a wide range of applications. Therefore there is no reason why the potential to use CFLs in the existing fixtures, identified in the technical survey, could not be realised by the householder given the necessary knowledge.

4.10 CONCLUSIONS

The cultural survey reveals greater similarities in people's lighting requirements between the three Northern European countries of Germany, Sweden and the UK compared to Spain. There is a stronger preference for clear/bright light in Spain, while the expectation that the Swedes would want cosy/soft light was not borne out by the evidence.

CFLs are perceived as providing a clear/bright light by the majority of owners in Germany and Sweden, whereas opinions were more evenly distributed in the UK and Spain, natural light being a popular choice among the Spanish. Among those non-owners who expressed an opinion, the majority also considered CFLs to provide a clear/bright light. In all countries, there was a shift in perceptions of CFLs between owners and non-owners, with a greater proportion of owners viewing CFLs as giving a soft/cosy light.

Common to all four countries was the lack of opinion expressed by non-owners on the characteristics and performance of CFLs, with few expressing strong negative opinions. Many non-owners had not actually considered purchasing CFLs. There is no real incentive for them to do so, particularly if they are happy with their current lighting. Therefore, people are more likely not to own CFLs through ignorance, rather than because of a dislike of the bulbs. Non-owners need to be shown that CFLs can match their requirements and their fixtures, but they will require guidance on how and where to use them in order to gain maximum benefit and satisfaction.

On the whole, owners are satisfied with their CFLs, although they were not always positive about them. The Germans expressed the strongest negative views about CFLs, the environment being a stronger motive for installing CFLs than their performance or aesthetics. In Spain, people chose to have CFLs because they like the quality of light. The main benefit of CFLs is judged to be the financial savings that can be made, whereas the main barrier to their adoption is the high initial cost and the majority of non-owners were unaware that CFLs save money in the long run. There was also uncertainty about the technology, even among owners.

Since the majority of owners are happy with their CFLs, there is no reason to expect them to change back to using ordinary incandescent bulbs, although there is a risk of reversion if they do not keep spare CFLs. A move towards dedicated fixtures would guarantee against changing back as well as ensuring optimal performance of the CFL, possibly improving peoples' level of satisfaction. Positive experience of integral ballast CFLs lays a good foundation for the introduction of dedicated fixtures. Householders would also benefit financially because of the cheaper replacement bulbs. The reduction in wastage, through incorporating the ballast into the fixture, is likely to appeal to the strong environmental motives in Germany. The cultural survey indicates the type of light that fixtures in various locations need to provide, which should help ensure their success.

Essentially, the cultural survey has succeeded in highlighting a number of key aspects of the lighting needs and perceptions of a cross-section of EU countries. Although there are limitations to the study, it has brought a better understanding of where there may be specific lighting demands for individual activities and between countries.

CHAPTER 8: CONSUMPTION TRENDS

The type of lighting people choose for their homes is dependent upon both cultural and technical factors - a combination of their attitudes to lighting and the technologies available on the market - as well as economics. The amount of electricity used for lighting depends on the way in which people then use the lights they have chosen. Hence there is a significant interplay between lighting technologies and cultural attitudes in determining lighting electricity use and hence the level of savings possible.

Reliable information on household lighting electricity consumption is not available for the majority of European countries. Studies monitoring consumption, either through hours of use or actual consumption, are costly and difficult to set up, often requiring separate metering equipment for each light. Measuring lighting electricity use is particularly difficult for fixed lights if they are connected to the general electrical circuit in the house, since there is no easy way of identifying the amount of electricity going into lighting alone. Hence, in many studies, lighting electricity use is often included in the miscellaneous category of electricity remaining when other end uses of electricity have been monitored.

Models of consumption provide an easier and cheaper alternative to improving estimates of lighting electricity use. This still requires a variety of data such as sales, ownership, average wattage of installed bulbs, and confidence in the model output is highly dependent on reliability of the input data. Due to the lack of such data, lighting consumption in all fifteen EU Member States could not be modelled, as was originally intended. As part of the detailed case studies of Germany, Sweden and the UK, sales data were purchased in order to model lighting consumption in these three countries. Actual measurements of household lighting consumption are useful to validate the model output. However, such figures were only available for the UK for this study.

A brief outline of the modelling process is given, taking a ‘stock model’ approach, before presenting results of the three scenarios modelled. The Reference Case (RC) scenario provides a base line for past and future lighting consumption. The other two scenarios, the Economic and Technical Potential (ETP) and the Fixtures and Immediate Technical Potential (FITP), illustrate the potential level of savings that are available through the installation of more energy-efficient lighting. More details on the modelling process and results are included in Chapter 8 of the Supporting Material.

4.11 MODELLING LIGHTING CONSUMPTION

Lighting electricity consumption was modelled using a ‘stock’ model approach that takes into account the time-related effects of new bulbs entering and old ones leaving the stock and enables the evaluation of the likely effect of policy options on consumption. This type of model is essential for analysing the effect of changes in technology or usage through time.

Stock models estimating lighting electricity use were constructed using a bottom-up approach (ie from the household perspective, rather than a top-down econometric approach), based on the data listed below. Ownership figures were checked by comparing them to figures derived from sales data and expected bulb life spans. The model outputs were then cross-checked against measured consumption data. The data used were:

- number of households,
- average household ownership of each bulb type,
- sales of each bulb type to the domestic sector,
- average wattage of these bulbs,
- expected average lifetime of these bulbs and

- measured household lighting electricity consumption data.

The actual data obtained for each of the three countries varied in quality and completeness, although missing data could be interpolated to some extent from what was available. In some cases, it was necessary to use results from the technical surveys, conducted as part of this project. Despite the fact that these were based on very small samples and were not nationally representative, they were valuable in the absence of other data. Light bulb sales data were purchased from the same market research company, GfK, for all three countries to ensure the maximum comparability and compatibility of data. A summary of the ownership figures used in the RC scenario is given in Table 8-1, including projections to 2020 based on the identified trends and expert judgement.

Table 8-1 Average household light bulb ownership, Germany, Sweden and UK, 1970, 1997 and 2020

	Germany			*Sweden*			*UK*		
	1970	1997	2020	1970	1997	2020	1970	1997	2020
Household numbers (m)	27.9	37.8	41.2	2.6	4.1	4.7	16.1	24.2	28.5
Total number of bulbs	10.4	30.3	33.2	13.8	40.4	44.3	11.0	20.1	24.0
Number of CFLs	0.0	2.1	3.9	0.0	0.4	1.8	0.0	0.7	3.2
Number of halogens	0.0	2.0	2.5	0.0	2.6	3.3	0.0	0.1	0.4
Number of fluorescent strips	0.5	2.1	1.4	0.7	2.8	1.9	0.5	1.4	1.0
Number of incandescents	9.8	24.9	25.5	13.1	34.5	37.4	10.4	17.9	19.4

Many of the figures used as inputs to the models are not exact, but represent best estimates, so the output of the models include expert judgement. The level of confidence in these results are shown by confidence limits on the consumption graphs (Chapter 8, Supporting Material). Uncertainty is greater the further into the future data are projected and confidence is lowest in the estimates for Germany since data were particularly limited.

4.12 REFERENCE CASE AND SAVINGS POTENTIAL

The Reference Case scenario gives historical lighting consumption, from 1970, with a projection up to the year 2020. The projections of usage and ownership and the underlying rate of technology change are determined from historical trends where possible. The only policy interventions allowed for are those that have been implemented or are close to implementation at the national or EU level, although the effect of the EU Energy Label on bulbs is not included.

Two scenarios were modelled to illustrate the level of savings available for lighting: the Economic and Technical Potential (ETP) and the Fixture and Immediate Technical Potential (FITP). These are both technical scenarios in that they are based on changes in the rate of introduction of efficient technology (CFLs), rather than any change in behaviour and so may not represent the lowest levels of consumption achievable. They assume the same overall trends in total bulb ownership and hours of usage as the RC scenario, the difference being in the timing and extent of the switch from GLS bulbs to CFLs. Ownership of halogens and fluorescent strips are kept the same as the RC scenario and there is no introduction of other technologies, such as the IEA ‘future bulb’.

The Economic and Technical Potential (ETP) is technically feasible and cost-effective to the consumer. However, what is considered cost-effective depends on the price of the bulb, the cost of electricity, the lifetime of the bulbs and the discount rate chosen - all these parameters will vary through time. For instance, the cost of CFLs is already decreasing and will be reduced even further by a shift to dedicated fixtures, improving cost-effectiveness and altering the ETP level. Therefore, the ETP scenario described here is an illustration of what could be achieved given current technology and prices. The definition of ETP requires the cost of a product to be paid back within its lifetime. Given the long life of CFLs, the average time a CFL would last in a home with a majority of CFLs would be around 12 years - some bulbs in lower use areas could last up to 30 years. Therefore it can be considered cost-effective, within the definition of ETP, to replace 80-85% of incandescent bulbs with CFL bulbs (DECADE 1997), assuming no constraints are posed by the existing fixtures in the house. Obviously, it is unrealistic to expect the ETP level to be reached by 2002, as in the model, but this is intended as a theoretical scenario to provide a target for policy and is only one illustration of how a certain level of savings could be achieved. An appropriate policy strategy is discussed in Chapter 9.

The Fixture and Immediate Technical Potential (FITP) scenario recognises that there are constraints from the fixtures already in the home - not all of them will take a CFL. Some fixtures take halogens or fluorescent tubes and will continue to do so. Of the remainder with incandescent bulbs, 46% in the UK (42% in Germany and 43% in Sweden) are in fixtures which are suitable for CFLs and could therefore be replaced immediately. For this scenario, it is assumed that 46% of GLS bulbs have been replaced by a CFL by 2002. It is also assumed that, beyond 2002, all new fixtures purchased as part of the natural turnover of the stock are suitable for CFLs. Since few data are available on the rate of turnover of fixtures, the final assumption is that all fixtures are capable of taking a CFL by 2020, thus reaching the ETP level of 80-85% of GLS bulbs being replaced by CFLs. This is a conservative approach as other developments in the technology of low-energy bulbs could take place, for instance CFLs could become smaller and suitable for a wider range of fixtures. In addition, savings beyond this level would be possible through the use of other energy-efficient technologies, such as the IEA ‘future bulb’, although these have not been modelled here since the emphasis is on CFLs.

The FITP is an important output from this study. It provides a realistic policy target and demonstrates the importance of treating the luminaire as a whole.

8.2.1 UK

Total residential lighting electricity consumption in the UK is 17 TWh in 1997, projected to rise under the RC scenario to 23 TWh by 2020 (Figure 8-1). Prior to the detailed research done by DECADE for the construction of a lighting stock model (DECADE 1995, 1997), total electricity use for lighting was estimated to be around 8TWh in 1997. This major revision to the lighting consumption figures has recently been confirmed through a study metering lighting undertaken by the UK Electricity Association (Palmer 1997, EA 1998). The DECADE stock model approach has been validated. The increase in consumption into the future is driven by a combination of rising number of households and a trend towards more bulbs per household.

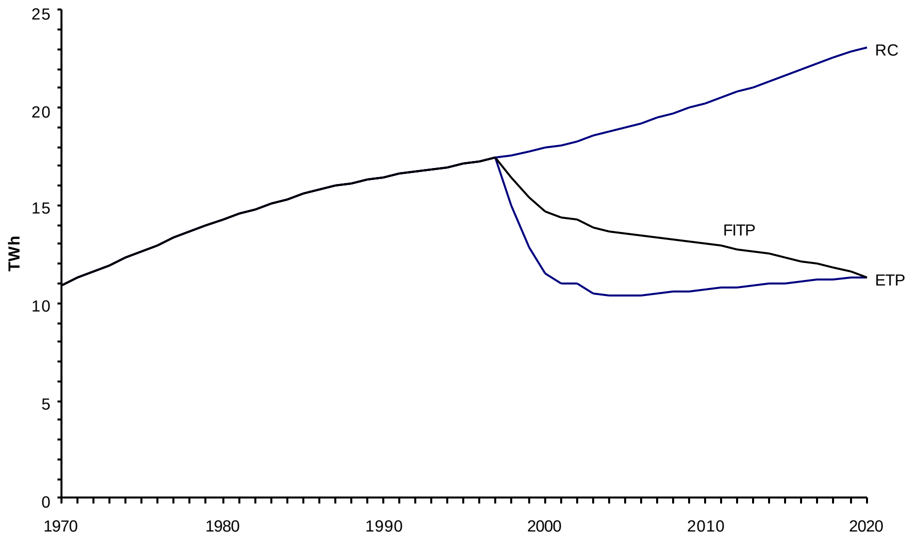


Figure 8-1 UK lighting electricity consumption under RC, FITP and ETP scenarios, 1970-2020

Lighting electricity consumption could be reduced to almost a half by 2020 as a result of switching to a majority of CFLs under the ETP and FITP scenarios. This represents a saving of over 400kWh per household.

8.2.2 Sweden

Domestic lighting electricity consumption in Sweden is estimated to be around 3 TWh in 1997 and projected to rise to around 3.5 TWh by 2020 under the RC scenario (Figure 8-2). This is mainly due to rising household numbers - average household lighting consumption actually falls over this period because of a greater proportion of CFLs and a decrease in the wattage of GLS bulbs used. Sweden is undertaking a major campaign to get three CFLs into every home by 2005 as part of the national programme to phase out nuclear power. This campaign is assumed to be successful in the projections. Despite higher numbers of bulbs in Swedish households, the average consumption per household (Unit Energy Consumption or UEC) of 760 kWh is similar to the UK figure of 720 kWh since the majority of these bulbs are of low wattage. The prevalence of low wattage bulbs means that potential savings are correspondingly lower, although savings of 36% by 2020 are still available under the ETP and FITP scenarios.

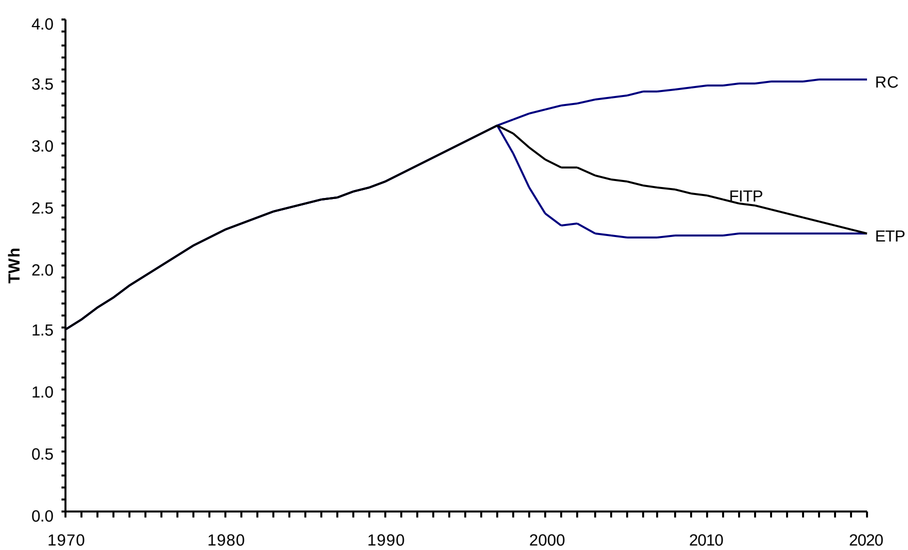


Figure 8-2 Swedish electricity consumption under RC, FITP and ETP scenarios, 1970-2020

8.2.3 Germany

In Germany, domestic lighting consumption is around 30TWh in 1997, only rising to 33TWh by 2020 under the RC scenario (Figure 8-3). Any increase in consumption due to the growth in household numbers and the expected trend towards high wattage halogens is offset by the lower wattage of GLS bulbs and an increase in CFL ownership. Average household lighting consumption is the highest of the three countries, at 775 kWh. As with the UK, this figure is far higher than previous estimates of lighting consumption, over double the official estimate of 300 kWh (VDEW 1997). It should be remembered that the stock model figures are the best estimates of consumption and are not exact - the true figure may lie somewhere between 450 kWh and 1100 kWh. However, even this lower limit is above previous estimates and actual household electricity consumption is more likely to be similar to that in the UK and Sweden. A detailed stock model has demonstrated the importance of domestic lighting in Germany: this will alter the emphasis given in policies.

It is not been possible here to identify the differences that may exist between former East and West Germany. Information gathered on the Eastern European countries in the country pictures indicate that these households are more likely to have lower lighting consumption than in the West. Therefore, while the figure of 775 kWh per household represents an average for all Germany, since it is based on sales figures for the whole country, there may be a very wide range in consumption between different households underlying this.

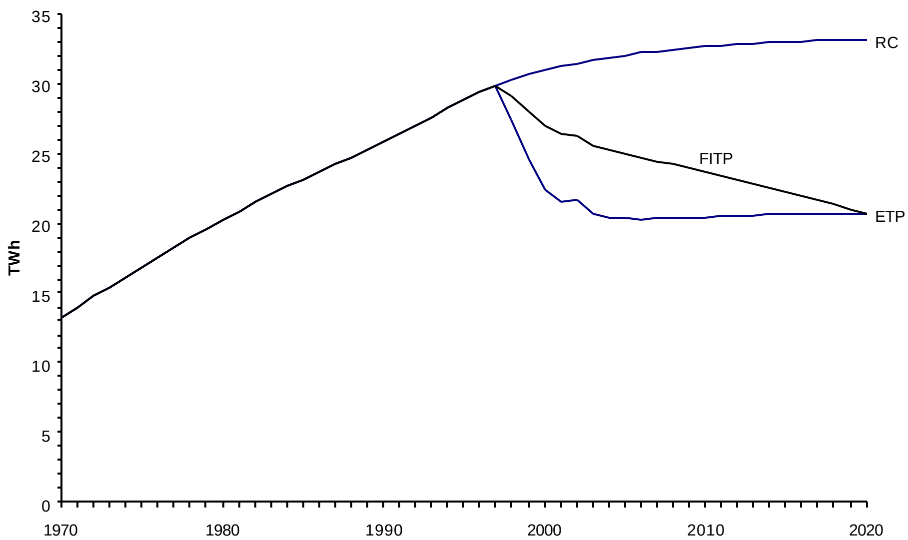


Figure 8-3 German electricity consumption under RC, FITP and ETP scenarios, 1970-2020

As in the case of Sweden, potential savings in Germany are lower than the UK because of the use of lower wattage GLS bulbs. Savings of 38% by 2020 are achievable under the ETP and FITP scenarios.

4.13 DISCUSSION OF RESULTS

8.3.1 Reference case

Average household lighting consumption is similar in all three countries (Table 8-2), despite differences in the number and type of bulbs found within households. This is partly because any savings resulting from the use of lower wattage GLS bulbs in Germany and Sweden are offset by the high number of bulbs per household. Also, the popularity of high wattage halogens in these two countries serves to increase consumption, thus negating any savings achieved through the higher ownership of CFLs in Germany. Total lighting consumption in each country is projected to increase into the future under the RC scenario, mainly driven by the growth in household numbers. There is also an expected trend towards more bulbs per household in the three countries, due to growing interest in lighting. This upward pressure on consumption is partly compensated for by an increase in CFL ownership. Hence, household lighting consumption decreases in Sweden while remaining fairly constant in Germany. In the UK, average household electricity consumption increases because the growth in CFL ownership is not enough to allow for the additional GLS bulbs in the stock, which are generally of a higher wattage than in the other two countries.

Table 8-2 Domestic lighting electricity consumption, RC scenario, Germany, Sweden and UK, 1997 and 2020

	Germany		*Sweden*		*UK*		*TOTAL*	
	1997	*2020*	*1997*	*2020*	*1997*	*2020*	*1997*	*2020*
Household numbers (m)	37.8	41.2	4.1	4.7	24.2	28.5	66.1	74.4
Household UEC (kWh)	775	805	762	749	721	811	758	804
Household expenditure (ecu)	125	129	61	60	72	81	102	106
Household carbon (kg C)	132	134	0	0	88	139	107	127
National electricity (TWh)	29.5	33.1	3.1	3.5	17.4	23.1	50.1	59.8
National carbon (MtC)	4.9	5.5	0.0	0.0	2.1	4.0	7.1	9.5
National expenditure (mecu)	4.7	5.3	0.3	0.3	1.7	2.3	6.7	7.9

Note: UEC - Unit Energy Consumption (average lighting electricity consumption per household)

In terms of CO_2 emissions, lighting in Germany is the most polluting given the dependence on fossil fuel electricity generation, high household numbers and highest levels of lighting consumption. Such emissions are minimal for Sweden because of the low percentage of fossil fuel generation, with 96% of generation from hydro-electric or nuclear power stations. Sweden is aiming to lower total electricity consumption and so reduce dependence on nuclear power, switching to renewable sources such as wind and hydro power instead. Actual emissions factors for Sweden were not available, but since CO_2 emissions are likely to be low they have been set to zero. The conversion factors used to derive the expenditure and CO_2 emissions are given in Table 8-3.

Table 8-3 CO_2 emissions conversion factors, Germany, Sweden and UK

	Germany	*Sweden*	*UK*
ECU/kWh - 1997	0.16	0.08	0.10
ECU/kWh - 2020	0.16	0.08	0.10
kg C/kWh - 1997	0.202	0.0	0.12
kg C/kWh - 2020	0.166	0.0	0.17

Sources: Country pictures and
Germany - Prognos AG (1995)
UK - DECADE (1997) based on EP 65 (1995)

8.3.2 Potential savings

Table 8-4 summarises the potential savings available under the FITP and ETP scenarios. These are identical for the two scenarios since they have both reached the same end point by 2020, the difference being the speed with which this was achieved.

It can be seen that a wide range of factors impact on figures for lighting consumption, including the number of households, the number of bulbs and the wattage of these bulbs. While some data are available to provide information on the current situation, attempting to identify future trends is far more difficult. However, since the figures estimated under all three scenarios are subject to the same likelihood of errors, estimates of future savings (RC less the FITP/ETP figures) are more reliable.

Table 8-4 Lighting electricity consumption and potential savings (electricity, expenditure and CO_2), Germany, Sweden and UK, 2020

		Germany	*Sweden*	*UK*	*TOTAL*
FITP/ETP	Household UEC (kWh)	502	482	398	461
	National electricity (TWh)	20.7	2.3	11.3	34.3
	National carbon (MtC)	3.4	0.0	1.9	5.4
	National expenditure (mecu)	3.3	0.2	1.1	4.6
Saving (RC-FITP)	National electricity (TWh)	12.4	1.3	11.8	25.5
	Percentage of RC	38	36	51	43
	National carbon (MtC)	2.1	0.0	2.0	4.1
	National expenditure (mecu)	2.0	0.1	1.2	3.3

Taking the constraint of the existing fixtures into consideration, as in the FITP scenario, only about half of the savings to be achieved under the ETP scenario are accessed by 2002. However, by 2020, total savings of 25.5 TWh could be achieved in the three countries under both scenarios, representing almost 30% of current EU lighting electricity use. This is equivalent to savings of 4.1 Million tonnes of Carbon.

As a proportion of the RC, savings are greatest in the UK because of the current use of higher wattage GLS bulbs compared with Sweden and Germany.

4.14 CONCLUSIONS

Detailed modelling of lighting electricity consumption has led to major revisions of previous estimates of lighting consumption in both Germany and the UK. The confirmation of the revision to the UK figures through actual measurements of lighting consumption gives greater confidence in the output of the stock model. Therefore, although no metered data are available for Germany at present, it is likely that lighting consumption is also far higher than previously thought. Hence lighting is more important as a policy focus since the potential savings are also much greater than thought. These revisions serve to underline the advantages of modelling as a way of checking estimates of lighting consumption.

The potentials for savings in this sector are large and quick to access, given the high turnover rate of bulbs in the stock. These exclude any behavioural change and therefore savings could possibly be greater.

The ETP scenario defines an envelope of savings, with the FITP scenario illustrating how this potential could be reached over a realistic time scale, once the existing fixtures are taken into account. In order to access these savings, appropriate policies are required, as discussed in the next chapter.

CHAPTER 9: POLICY

Following Kyoto, the residential lighting sector is particularly important as saving are both substantial and potentially available quickly. Without policy intervention, any reductions in consumption are likely to be realised slowly, if at all. In the past, policy has focused on other groups of domestic appliances, for instance there has been an EU Energy Label on refrigeration equipment since 1995 and on washing machines and tumble dryers since 1996. The opportunities for additional savings from the domestic lighting sector are now being considered.

A stronger focus on lighting is only one of the results of the climate change agreements reached in Japan in December 1997, the other new emphasis is on the need for guaranteed savings. The members of the European Union are collectively committed to reducing their emissions of carbon dioxide to 8% below the 1990 level by 2010. The effect of this commitment is that the outcome of policy must have a degree of certainty that was not previously necessary.

An estimate of lighting electricity consumption for the EU has been made based on the detailed modelling for Germany, Sweden and the UK presented in Chapter 8. The figures for all three scenarios (fully described in Chapter 8) have been extrapolated on the basis of the number of households in the EU and corrected to match the present national consumption figures, adding up to 86 TWh across the whole of the EU, given in Chapter 4 (Figure 4-1). Electricity consumption is projected to rise to 102 TWh by 2020 under the Reference Case scenario, with a conservative estimate for potential savings of 44 TWh (43%) achievable by 2020 across the EU (Figure 9-1).

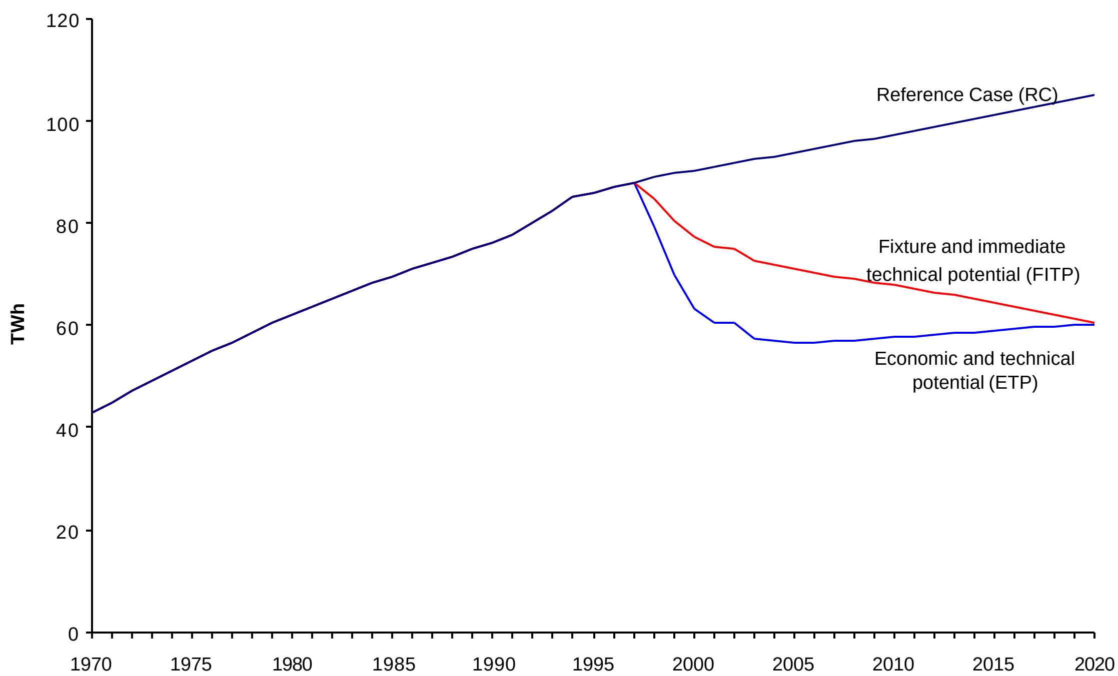


Figure 5-1 Estimated EU lighting electricity consumption under RC, FITP and ETP scenarios, 1970-2020

The ETP scenario defines the envelope of savings that could be accessed through policy, with the FITP scenario an illustration of one way in which this could be achieved. The FITP scenario is based on the finding from the technical survey that it is technically and aesthetically feasible to install CFLs in at least 40% of fixtures currently using incandescents, equivalent to around eight CFLs per house. Given the natural rate of turnover of bulbs, this is realistically achievable within five years. Following on from this, it is assumed that all fixtures purchased, either new or replacement in the natural turnover of the stock, are dedicated to CFLs. Therefore, by 2020, 80% of all bulbs in the household are CFLs. The largest savings will come from installing CFLs in the highest used locations - the technical survey demonstrated that by replacing only four bulbs in the highest use locations which are suitable for CFLs, annual savings of 200 kWh per house can be achieved. These need to be targeted first in order that later replacements become economically favourable. The only barrier to achieving this potential, given sufficient availability of CFLs, lies in persuading the householders to make the change.

Lighting is a particularly complicated sector for policy, because there are both bulbs and fixtures. These two technologies have different manufacturing industries and are sold through separate retailing structures, making a total of four groups of companies, briefly summarised in Table 9-1. These four groups have not traditionally co-operated, but collaboration will be important if the potential savings are to be realised.

Influencing the fixture industry in a coherent strategy is potentially difficult because of the large number of small, independent companies and because of imports from outside of Europe. The current market is still dominated by fixtures produced within Europe, but competition from the Far East is increasing. The luminaire retailers have potentially the most significant role in transforming domestic lighting. The absence of a trade perspective - there are few large chains of lighting shops - may inhibit this development and indicates why external schemes, such as accreditation, may be necessary.

Table 5-1 Main constituents of domestic lighting manufacturing and retailing markets

	Manufacturers	**Retailers**
Bulbs	Three large multi-national companies	Supermarkets
Fixtures	Numerous, small, often country-specific	Specialist shops, department and DIY stores

There are further complexities specific to lighting, in addition to those found with all other domestic appliances where market transformation is now the accepted policy strategy. Lighting policy options have to recognise that:

- there is multiple ownership of light fixtures in the home, requiring multiple interventions, over a long time period;
- lighting is used by different people for a variety of tasks and attitudes to ‘acceptable’ light vary in households and across countries;
- each fixture has a different usage pattern which implies differing levels of cost-effectiveness when replacing with more energy-efficient alternatives;
- ownership of fixtures varies across Europe, from being personal possessions in some countries to part of the fabric of the house in others;
- the replacement rate of bulbs is rapid, but turnover is slower for fixtures.

5.1 POLICY FOCUS

The synergies available from a strategic policy approach are greater in lighting than with other appliance groups. This is because there has been relatively little attention paid to lighting so far and because of the additional benefits available when the fixtures and the bulbs are both considered. In addition to the fragmentation of the industries involved and the need for certainty, this project has, through findings and through debate, established the major objectives for a market transformation policy on lighting in Europe.

There are two main policy phases, in parallel:

- **to get the first CFL into those households that have none as soon as possible**. One of the key findings is that, throughout Europe, those households that have a CFL have an average of three or four. However, there are still around 70% of households that currently have no CFLs. The non-users are either unaware that CFLs exist or uncertain about their attributes. The owners, however, are generally positive about the quality of light and other benefits of CFLs, which can explain why they have several in the house. The practical experience of using a CFL seems to be vital if people are to be converted from doubters into happy users.

- **to ensure that the majority of fixtures in households are dedicated to CFLs in the longer term**. The ultimate focus of any strategy must be a move towards dedicated fixtures, so that the savings are certain and there can be no reversal to incandescent bulbs and higher consumption. This has to be a long term goal, partly because there are few attractive dedicated fixtures available at present and also because of the slower turnover of fixtures in the home. Once appropriate luminaires are designed and as people become used to CFLs in the home, then the adoption of dedicated fixtures will be both acceptable and natural.

The focus on integral ballast CFLs in the short term is, therefore, a necessary precursor and provides the opportunity for policies targeted at fixtures to be developed. The different state of the bulb and fixture markets means that they are, initially, at different stages of market transformation. The combination of these two phases and their eventual synchrony requires a coherent strategy, as in market transformation, to ensure that the savings are achievable and at a reasonable rate. Before considering the details behind policy formulation for Europe, a brief outline of the theory of market transformation is given followed by an example developed for domestic lighting in the UK.

5.2 MARKET TRANSFORMATION THEORY AND LIGHTING

Market transformation is the process by which a significant and permanent improvement in the efficiency of products sold can be brought about, more quickly than would have happened without intervention (DECADE 1997). Isolated policies have a limited impact, but they can create a powerful synergy when combined into a coherent strategy. The appropriate package and sequence of policies is specific to each product and requires consideration of the characteristics of the appliance group and wider policy objectives such as the certainty of savings, cost (to government, consumers and manufacturers) and equity between income groups.

Market transformation takes a long-term view (typically 10-15 years) using a combination of market building and market consolidation activities, both equally important:

- the first requirement is a reproducible measure of consumption and efficiency, and to incorporate this in an energy label. Once efficiency can be measured, it can be monitored and influenced;
- the market building stage aims to increase the market share of more efficient technology through, for example, procurement and rebate programmes, likely to be undertaken at the national level. The aim of these policies is to get the efficient technologies to achieve a certain proportion of the market (say 20%);
- in the market consolidation phase the aim is first to make these energy efficient technologies the average on the market and then the minimum standard. At this point, 100% of the savings are achieved. This involves instruments such as regulatory or voluntary agreements, usually implemented at the EU level. Regulatory incentives remove uncertainty and create the best climate for investment and product development.

Further details on the theory of market transformation are given in Chapter 9 of the Supporting Material or in DECADE (1997).

A market transformation strategy for lighting, including both incentives and standards, is a relatively new concept. Any programme developed will be more complex than that required for other domestic appliance markets since lighting represents two distinct but inter-dependent technologies and their associated industries - light sources and light fixtures. As depicted schematically in Figure 9-2, the components of such a strategy include labels, education, procurement, rebates, efficiency standards and regulation.

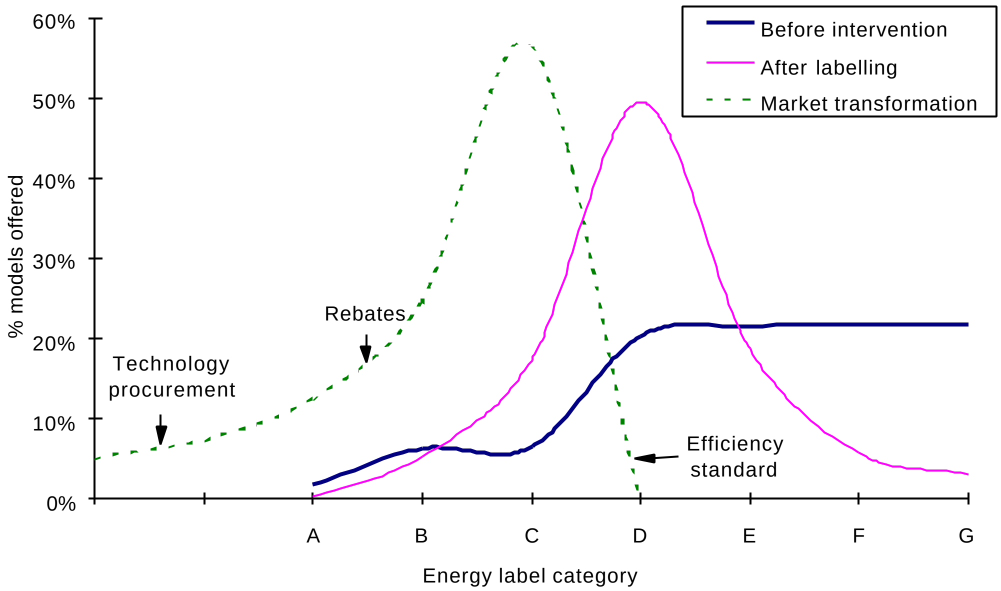


Figure 5-2 Three stages in transforming the market

Market transformation focuses on stimulating the purchase and use of more efficient technologies. It does not take account of any change in behaviour in terms of the way in which the lights are used, such as switching the lights off when they are not in use. However, information on wasted lighting energy is scarce and any such savings are likely to be minimal in comparison to what could be achieved through the installation of efficient technology.

5.3 A CASE STUDY OF THE UK

The DECADE team has developed a detailed market transformation strategy for domestic lighting in the UK, using a mixture of national and EU policies (DECADE 1997), which is summarised here to demonstrate the way in which policies could interact. It is not proposed that this is the appropriate scenario for Europe, but it provides a useful exemplar. For the UK, one of the main objectives was to achieve the ETP level by 2020 in an equitable way - low-income households should clearly benefit from the strategy.

The aim, as in Europe, is to promote integral ballast CFLs in the short term combined with building the market for dedicated fixtures as the long term goal. This scenario is constructed on the basis that there are 24 million households with an average of 20 bulbs per household in 2000. The ETP level at 2020 is equivalent to 85% of all bulbs being CFLs, which requires the market to be built up to and maintained at an annual sales volume of around 24 million CFLs. This is equivalent to one new CFL per household per year, not including replacement bulbs. The contribution of various policies towards achieving this target is illustrated in Figure 9-3.

Current market building polices at the national level are continued, such as programmes run by the Energy Saving Trust (EST) to distribute or subsidise CFLs, so that by 2003 every household has two integral electronic ballast CFLs. In addition, the EST is developing a scheme to promote dedicated fixtures and it is assumed that successful designs are manufactured and subsidised until 2005. As the average household purchases a fixture each year, whether new or replacement, the aim is for an increasing proportion of these purchases to be dedicated, so that by 2005, each home has two dedicated fixtures. Hence, in the four years from 2001, the average home will have acquired four CFLs (two of which are in dedicated fixtures).

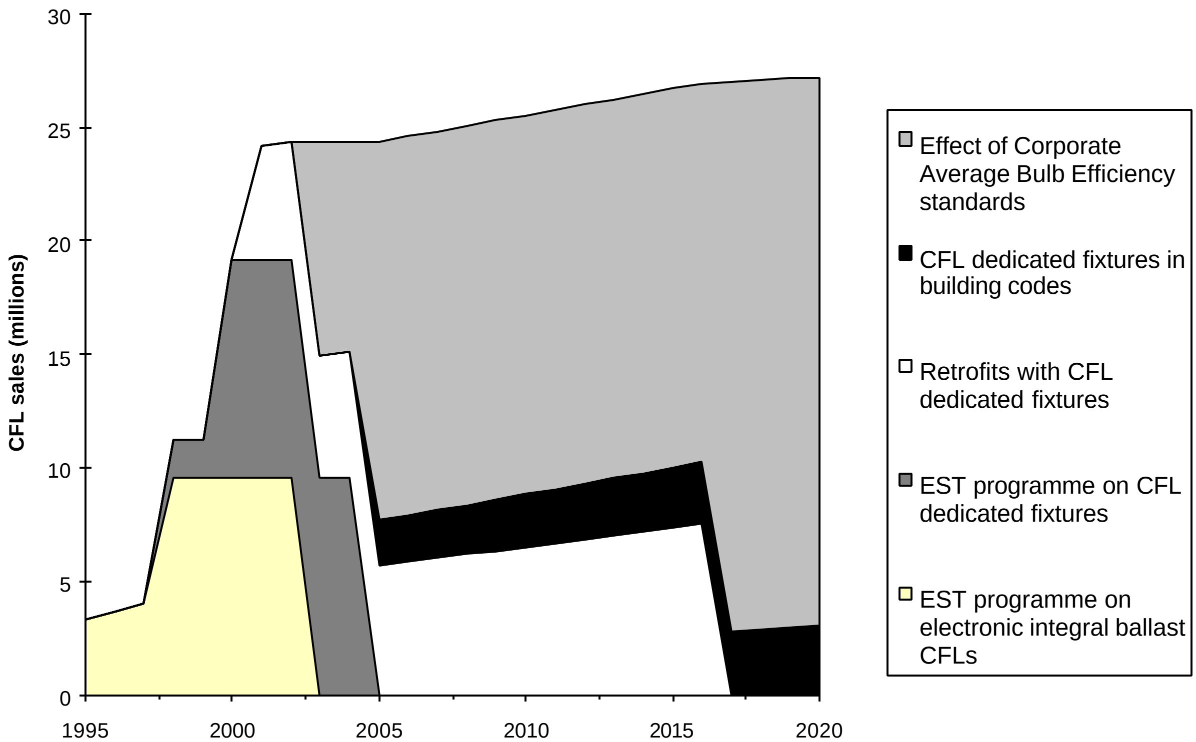


Figure 5-3 Transformation of the UK domestic lighting market: effects of programmes to 2020

Source: DECADE 1997

The market is further developed through a retrofit programme, over fifteen years, to install dedicated luminaires in 8 million households; mainly low-income. This policy serves the function of both confirming the market for dedicated fixtures and making sure that low-income households benefit from the energy savings at an early stage. Once these policies have built the market sufficiently, specification of dedicated fixtures in the UK Building Regulations underpins the transformation. This is possible in the UK since the majority of light fixtures are considered part of the building fabric. This would affect 200 000 new homes per annum, guaranteeing future markets. These last two policies - tailored to the UK situation - complete the market building stage. In other countries, alternative national policies may be needed.

These national policies achieve 35% of all the savings. This is a substantial proportion, because of the need to ensure that both CFLs and dedicated fixtures are firmly established. With lighting, it will not be possible to regulate and prevent the sale of the less efficient technologies, such as incandescent bulbs, in the way that inefficient fridges or washing machines can be banned. This is because the householder will continue, for many years, to own fixtures that are designed for GLS bulbs and should be free to purchase these traditional bulbs. The interaction between bulbs and fixtures and the substantial number of luminaires per house requires particularly careful policy design.

The consolidation of the market implies co-operation across Europe to achieve the remaining 65% of savings. The form of this collaboration will depend upon the speed with which electricity savings are required. In this UK example, the aim is that by 2020, CFL sales will account for half of all bulb sales and around 80% of burning hours in the average household. The target could not be reached earlier, because of the large number of fixtures and bulbs involved per household. These remaining savings would be achieved through the agreement with the bulb manufacturers of an EU Corporate Average Bulb Efficiency (CABE) - see Section 9.7.2.

5.3.1 Other member states

The design of a similar strategy for other EU member states will depend on factors specific to each country at the market building stage. At the national or local government level, the importance given to lighting and to electricity will be affected by the country's target for CO_2 emissions in 2010 and whether electricity is a major source of these emissions. Other factors, such as the importance of domestic lighting as a component of peak electricity demand - the level of maximum electricity demand dictates the amount of generating capacity and distribution networks required - will determine whether the utilities will be potential collaborators. However, the role of common and co-ordinated policies, like CABE, would be the same for the whole EU. Before considering the factors that need to be covered by policies, past and existing policies are reviewed. These demonstrate the extent to which governments are already involved in policy and what lessons can be learned.

5.4 EXISTING POLICIES

5.4.1 Past and present lighting campaigns

In many EU countries the market for integral ballast CFLs has been developed through national programmes aiming to lower peak electricity demand and reduce CFL prices. This has usually taken the form of subsidised or free CFLs supported by some combination of government, utilities, manufacturers and retailers at a regional or national level. Rebates at the point of sale have been the most common method employed, often funded by the utilities. Further details of past and present campaigns are included in Chapters 2 and 5 of the Supporting Material. Lessons learnt from these campaigns include:

- the duration of the campaign is important, with longer campaigns being more successful;
- liaison is needed between the utilities, manufacturers and retail outlets to ensure that stocks will meet demand during campaigns;
- the provision of consumer information can increase the effect of financial incentives (Mills 1991);
- there can be a large indirect effect, with an increase in CFL sales outside the campaign period (Willerstrom 1995). These may be purchases of second or subsequent bulbs from householders who are happy with their first CFL;
- involvement of the local political and administrative authorities in the campaigns often engendered a sense of local pride and responsibility which contributed to the success of these programmes (Herbert 1993);
- a 'pay-on-the-bill' approach has proved particularly successful in Denmark and the Netherlands (Mills 1991);
- giving away CFLs is more effective than through rebates or marketing alone (Thomas *et al* 1998);
- a rebate did not necessarily lower the price in the shops after the end of the promotion;
- publication of a CFL 'quality list', based on tests on reliability, helped consumer confidence;
- there was a lack of correlation between incentive levels (bulb price) and programme penetration rates, suggesting that it is the delivery mechanism that is important, with different consumer groups preferring different types of incentives (Mills 1991).

There have only been a few schemes focusing on dedicated fixtures. Sweden and Poland have run design competitions on dedicated fixtures in the past and EM (Swedish National Energy Administration) is currently running a procurement programme for energy-efficient fixtures in conjunction with Ljuskultur (Swedish National Lighting Trade Organisation). In the UK, there are plans for a dedicated fixture subsidy scheme and for the installation of dedicated fixtures in newly built accommodation provided by Local Authorities and Housing Associations.

The first phase of a more structured market transformation policy is to ensure that each household has been given a free CFL, bringing these piecemeal campaigns together. It is not clear how many of the bulbs in people's homes across Europe have been obtained as a result of these rebate and subsidy programmes - in the UK, it is around a third of all CFLs installed. Therefore, in order to work towards this objective, each country needs a list of the schemes undertaken to date, collecting any available information on the households that have already benefited.

5.4.2 Phasing out magnetic ballasts

The Commission is currently preparing a proposal for an EU directive, introducing a minimum efficiency requirement for ballasts. An energy efficiency index for bulb-ballast systems was recently agreed by the European ballast manufacturers, represented by CELMA (Committee of European Lighting Manufacturers). This provides the basis for the proposed minimum standard by progressively removing low efficiency ballasts from the market, such as the early magnetic ballast CFLs. This will be undertaken in three stages from 2002 and completed by 2008. One effect of this will the removal of magnetic ballast CFLs from the market since high efficiency magnetic ballasts are too bulky for use with CFLs. This useful precedent demonstrates that the manufacturers recognise the benefits of concentrating the market on the more efficient CFLs.

5.4.3 EU Energy Label for light bulbs

The Energy Label for electrical household bulbs is already a developed policy: it is due to be implemented in the year 1999, but there is an interim period before it is completely mandatory in 2001. The label gives each bulb a rating on a scale of A to G, similar to the cold and wet Energy Labels, with A representing the most efficient light source and G being the least efficient (Figure 9-4). The size will be as in the illustration, unless it has to be reduced to fit on the packaging. The rating is calculated on the basis of the wattage and light output of the bulb, giving the following classifications of current technologies (Borg 1997):

A - tri-phosphor fluorescent lights (linear strips and pin-based CFLs) and integral electronic ballast CFLs
B - halo-phosphor fluorescent lights (linear strips and pin-based CFLs) and integral magnetic ballast CFLs
C - efficient halogen bulbs
D - other halogen bulbs
E/F - standard GLS bulbs
G - very poor incandescent bulbs

Figure 5-4 EU Energy Label for light bulbs

The only other new information to be included, in addition to the information normally given on the packaging, is the luminous flux of the bulb (a measure of light output). The average life of the bulb (in hours) will only be included on the label if the packaging already shows information on bulb life. Efficacy of the bulb will not be stated explicitly since this was not considered to be a fair comparison between all light sources, but it can be derived from information on the luminous flux and wattage of the bulb. The impact of the label may be limited since information given for the different bulb types will vary and will therefore not be directly comparable (eg expected lifetime may not appear on the label for incandescent bulbs). However, it is hoped that it will provide greater confidence in the benefits of CFLs and help ensure the quality of these bulbs. It will also raise awareness of the label in general since light bulbs are a frequent purchase. The Energy Label is a major step towards enabling consumers in the EU to make an informed choice about the bulbs they buy and provides the basis for market transformation of the light source market.

5.4.4 Summary of present policies

Policies are already in place to ensure that householders are encouraged to use more efficient bulbs, particularly CFLs, in their homes. The market transformation process is underway, though the separate policy components are not yet part of a clear, structured and targeted strategy. The two immediate priorities are to provide consumer education on CFLs and to stimulate the design of dedicated fixtures.

5.5 PROCUREMENT PROGRAMMES AND DESIGN COMPETITIONS

Consumer demand is restricted at present due to the current lack of well-designed CFL fixtures suitable for residential use and those that do exist are usually specific to a wattage and a type of bulb - this needs to be overcome with a more standardised approach. Procurement programmes could tackle both these issues to produce well-designed dedicated fixtures that can take a range of CFLs, reflecting the flexibility of GLS bulbs and fixtures. Compatibility and comparability of technologies is crucial to the success of any move towards dedicated fixtures. People have to know that they will still be able to buy replacement bulbs for their fixtures in years to come. This will require close and continuing liaison between the bulb and fixture manufacturers. Such collaboration has been particularly effective in developing the market for halogen luminaires.

High profile design competitions, with wide media coverage, for new and original dedicated fixtures reflecting consumer priorities, would provide a good basis for any procurement programme, promoting awareness of this technology throughout the general public. A catalogue of the various designs available could also be effective in encouraging purchases and raising awareness.

The fixture market requires a slightly different approach to the bulb market, since it involves a greater number of players, including builders and architects, as well as the householder. While this provides more opportunities to influence the market through these different channels, equally transformation of this market presents more of a challenge because of the variety and diversity of fixture styles and types available. These need to be replaced by an equivalent range of dedicated fixtures.

Dedicated fixtures are already common in the commercial sector where the incentive and ability to invest in the technology is much greater - the savings, both in terms of electricity and labour costs (because the bulbs need replacing less often), are large and quickly realised. Although these fixtures may not be appropriate for the residential market, they provide a good basis for identifying successful designs. The results from the technical survey, indicating the particular types of fixtures found in high use locations and which types are currently unsuitable for CFLs, also provide guidance on where efforts for dedicated fixture design could be most effective.

5.6 THE ROLE OF EDUCATION - BUILDING A POSITIVE IMAGE

The campaigns to promote free or heavily subsidised CFLs have not always incorporated guidance to the householder on how to use the bulb effectively in the existing fixtures. Without awareness of some of the technical characteristics of both CFLs and fixtures - and the way they interact - there is a danger that people will have placed CFLs in inappropriate fixtures, resulting in poor light output and uncertainty about the technology. An efficient bulb is devalued if used in an unsuitable fixture. As outlined earlier, there is already confusion surrounding CFLs. The negative views of CFLs will increase if people continue to obtain bulbs without guidance on how to use them properly.

An early development should be the production of clear leaflets to be given out with each CFL, so that they can be used effectively in people's existing fixtures.

This would enable another obstacle to be overcome: advice is not available at the point of purchase of a bulb since the majority of replacement bulbs are bought in supermarkets and retail staff there are unlikely to be well-informed about lighting issues. In addition, people are not used to, and possibly not aware of the need to ask for advice when purchasing light bulbs. A leaflet at the point of sale would help all consumers obtain a better understanding of the interaction between the bulb and the fixture, whether in their existing fixtures or in new purchases.

At the moment, it is not easy for householders to obtain a CFL on a trial basis and impossible to get expert advice in the home, where the fixtures are. Many German utilities have 'CFL test suitcases' which allow customers to try out a range of CFL types for free. An alternative approach to enable experimentation would be for retail outlets to offer 'no-questions' refunds if the bulbs were returned within a certain time period, encouraging people to try out the bulbs. A reliability 'quality list' for CFLs, as used in Denmark and Sweden, would also help provide consumers with confidence in the products.

5.6.1 The retail environment

Across the EU, 70% of households - over 100 million families - do not have a single CFL in the house. Those households that do have CFLs are having to teach themselves, by trial and error, how to identify which fixtures are most appropriate. Many of the participants in the technical survey stated how much they appreciated the opportunity to discuss with an expert how to obtain the best light from a CFL. At the same time, there are few articles in the media and magazines to inform the public on the lighting characteristics of different bulbs. It is not surprising that there is ignorance and confusion.

The difficult task is to see how such advice can be provided for householders. It may never be possible to provide detailed information to consumers when they purchase their low-energy bulbs in supermarkets. Educating householders will have to be achieved through other means. The obvious channel is through luminaire retailers, though the assistants may not always be well-informed at present. The recommendation is that:

The retail environment for luminaires is transformed into a showcase for low energy lighting.

This will require several policy initiatives, explained in more detail below, if consumers are to be provided with good quality advice:

- a label on a fixture to identify which bulbs can be used in it;
- a fully trained workforce, with incentives to understand and promote low-energy lighting;
- displays of fixtures that are suitable for CFLs.

A label for fixtures

There are no proposals in existence for a label on fixtures. The technical survey demonstrated that there are a large number of fixtures designed for incandescent bulbs that could not be considered suitable for

CFLs. However, at the moment, there is no easy way for a consumer, when buying a fixture, to identify if it is suitable for use with integral ballast CFLs and which type of CFL would work best. Such information could be provided by a fixture label, corresponding to information given with the bulbs as to the type of fixtures they are suitable for. Thus, the fixture could be identified as suitable for, say, certain types of A rated bulbs. The criteria to qualify for the label should be simple and easy to apply. This process would encourage collaboration between the bulb and fixture industries, stimulating designs of incandescent fixtures suitable for integral ballast CFLs, with a natural progression towards dedicated luminaires.

Retail staff training and consumer support

The provision of labels on bulbs and fixtures is important for further policies, but the impact of the labels themselves depends upon the support provided in retail outlets. This is particularly true for lighting, where the efficiency of the system as a whole depends upon the efficiency of both the fixture and the bulb. The role of retail staff is particularly important in the promotion of dedicated fixtures, requiring an awareness of the additional benefits of these fixtures. The provision of training courses for the retail staff could be undertaken in conjunction with the light bulb manufacturers. A national accreditation scheme would make it possible to identify those shops where the staff are trained to a specified standard with regard to energy-efficient lighting.

Retail displays

One way of tackling several issues simultaneously would be for retail outlets with lighting showrooms to fit all - or the majority - of the fixtures on display with integral ballast CFLs. Ideally, this would be done in conjunction with a fixture label indicating suitability for CFLs and would serve several functions:

1. It would demonstrate to consumers that CFLs can work well in the similar fixtures they have at home, producing an appropriate light, thus bridging the gap between knowledge and experience. It would also guide them to the most suitable type of bulb to use with a particular fixture.
2. The retail staff would have practical examples to demonstrate the types of CFLs available and be more aware of the issues to consider when using them in fixtures originally designed for incandescent bulbs.
3. The retail outlets could make substantial savings in electricity as well as air conditioning, since the heat generated would be far less with CFLs.
4. Dedicated luminaires will gradually replace the incandescent fixtures currently on show as the range available increases.

A further extension of this would be to sell all fixtures with the appropriate integral ballast CFL already installed. In future, the householder could just replace the CFL with an identical bulb and would avoid the need to learn about some of the technical issues.

In combination with any approach designed to increase CFL ownership, appropriate disposal mechanisms need to be developed, to avoid mercury and phosphor pollution. While these may be in place in the commercial sector, such mechanisms are not readily accessible to the general public, in addition to which, many people are unaware of the need for careful disposal of old CFLs. A system whereby the used bulbs could be returned to the point of purchase, with a refundable deposit providing an incentive, could be effective (DEFU 1996) and again would get people into specialist lighting shops.

This suite of policies demonstrate ways in which the industries and policy makers could collaborate to ensure that people have access to good advice, particularly on how to use integral ballast CFLs in both fixtures in the home and new purchases.

5.7 INFLUENCING THE MARKET

5.7.1 Rebates and subsidies

It is not possible to identify the scale or scope of individual national rebate schemes that will ensure every household has a CFL. However, major national rebate schemes, funded by national government or the utilities, are an important part of the strategy and require careful targeting.

Rebates and subsidies for dedicated fixtures to increase their market share will be appropriate only once a range of fixtures is available. In the UK example explained above, there were both rebates for dedicated fixtures in the shop and retrofit programmes to get them installed in low-income homes. The latter would be less important in other countries, where few fixtures are part of the building fabric. Similarly, in certain countries, specification of dedicated fixtures in the building regulations could form part of the consolidation process as well as further guaranteeing future sales of pin-based bulbs.

5.7.2 Negotiating targets

In addition to rebates and subsidies, agreements to improve the efficiency of the average bulb sold by the manufacturers help to transform the market. These two policies are mutually supportive and increase the speed with which savings from lighting are achieved. The Corporate Average Bulb Efficiency (CABE) is proposed as such an agreement (Figure 9-3), designed to achieve several objectives (DECADE 1997, Hinnells 1997):

- to give a framework to the long-term structure of domestic lighting in Europe, with clearly defined targets. These provide the boundaries (maximum and minimum, depending on where the bulbs are installed) for future savings, as guidance for government in climate change negotiations;
- to provide a focus for the manufacturers of both bulbs and fixtures for new designs and production capacity;
- to establish a basis for discussions on a negotiated directive, rather than a voluntary agreement, if the role of imports are to be included;
- to provide wide flexibility and continuing customer choice over the types of bulbs on the market, even in 2020.

This agreement, negotiated with the light source manufacturers, would set a target level of efficiency for the average bulb sold, that improves annually. CABE allows flexibility in shifting from a majority of incandescent sales to a majority of more energy-efficient bulbs, while recognising that there will always be a certain level of incandescent and halogen sales. This approach has the scope to incorporate other efficient technologies which may emerge in the future, such as the ‘future bulb’ currently being developed through an IEA procurement programme. In conjunction with a decision to phase out all integral ballast CFLs, this agreement would support the change to CFL dedicated fixtures. Collaboration between the bulb and fixture industries would enable bulb manufacturers to confirm that the appropriate dedicated fixtures are available in order that they may reach the targets set for CABE. A voluntary agreement by the lighting industries is the only way that has been identified to achieve the target set under the ETP scenario in a timescale that will contribute to the Kyoto commitments.

CABE is only an example for discussion. The opportunity exists to identify the contribution that the lighting industry can make to the reduction of carbon dioxide emissions. This is both a substantial challenge and a new perspective.

5.7.3 The role of manufacturers

The role of manufacturers is to ensure that the products are available in sufficient quantity and the role of retailers is to support the sales of these products with advice. The discussions on targets must include both sets of manufacturers, if the targets are to be met and manufacturing capacity is to be able to meet demand. If all households within the EU were to install four CFLs by the year 2002, this would require the annual production of over 420 million CFLs. Sales in Europe were only 120 million CFLs in 1997. However, sales have already doubled since 1993 and so this would appear achievable in terms of manufacturing capacity. Within this increase in production, there is a shift from integral ballast CFLs to CFLs for dedicated fixtures as the market for dedicated fixtures becomes more developed. Sales of pin-based CFLs currently represent 43% of world CFL sales and 50% of CFL sales in Western Europe, but these are mainly to the commercial sector.

Apart from the current production capacity, another issue is the reduced volume of sales in the longer-term, because of the longer life of bulbs. The domestic lighting is changing and will continue to evolve, whatever is the effect of additional policies to achieve greater energy conservation more quickly. The wider use of dedicated fixtures and electronic ballasts requires the light source manufacturers to become more involved with fixture production and the current manufacturers. It also opens up opportunities in the area of control systems. This could represent the next step in the development of lighting - once the bulb and fixture have become more integrated, lighting in the home can be treated as an overall system.

5.8 RECOMMENDATIONS

The key recommendations for transforming the lighting market are summarised here.

An inventory is made in each country of the CFL promotions that have already taken place and the lessons to be learnt from these. Information about known recipients will be collated, where possible. The objective is to ensure that every household has at least one CFL. Three particularly successful methods employed in the past have been:

- when a CFL is purchased, giving another for free;
- giving the CFL for free;
- purchasing the CFL through the electricity bill.

An early development should be the production of clear leaflets to be given out with each CFL, so that they can be used effectively in people’s existing fixtures.

Establishing a ‘quality list’ for CFLs that have been tested for reliability.

The retail environment in specialist lighting shops is transformed into a showcase for low energy lighting, requiring several policy initiatives if consumers are to be provided with good quality advice:

- a label on a fixture to identify which bulbs can be used in it;
- a fully trained workforce, with incentives to understand and promote low-energy lighting;
- displays of fixtures that are suitable for CFLs.

Procurement of well-designed, dedicated fixtures, perhaps in conjunction with competitions, is needed as soon as possible. The resultants designs should be widely publicised in the media and provided with rebates initially. The rebate could be the inclusion of the appropriate bulb, for free.

Clear targets agreed with industry, for instance in the form of a Corporate Average Bulb Efficiency, to establish the direction for design and manufacturing capacity and confirm the electricity savings.

The lighting market is in the process of being transformed and this revolution will involve all the players: manufacturers, retailers and all 150 million households in the EU. The savings could be accessed rapidly, contributing to the demanding targets for carbon dioxide reductions in both 2005 and 2010 and long after. These savings would not be realised by the market alone and require positive policy intervention. All EU countries face a considerable challenge, as agreed at Kyoto, and want to set a positive example in future climate change negotiations. The opportunities available in domestic lighting could be used to develop some powerful common and co-ordinated actions.

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APPENDIX A: GLOSSARY

ballast - a device to provide the necessary circuit conditions to start and operate discharge light sources, such as fluorescent or high-intensity discharge (HID) lights. The ballast:

- provides proper conditions to establish an arc between the two electrodes;
- stabilises light output by regulating the electric current flowing through the bulb;
- supplies the correct voltage for proper operation of the light source and may compensate for voltage variations in the electrical current.

base - the end part of a light bulb containing the electrical contacts.

bayonet base CFL - a CFL with a ballast that has bayonet base that fits into the standard incandescent light bulb socket. A bayonet base CFL may be modular (see modular system) or self-ballasted (see integral ballast CFL). Both types are designed to replace standard incandescent light bulbs.

bulb - see light bulb

CFL - see compact fluorescent light bulbs.

colour rendering index (CRI) - (of a light source) a measure of the degree of colour shift objects undergo when illuminated by the light source as compared with the colour of those same objects when illuminated by a reference source of comparable colour temperature (Illuminating Engineering Society of North America - IESNA). To determine the CRI rating of a specific bulb, eight standard colour samples are illuminated by a reference source (defined as having a CRI of 100, with a similar colour temperature to the test source), and the test source. The “shifts” in colour appearance between the two sources are tabulated, and the results averaged to give a single CRI number for the test source.

colour temperature - (of a light source) the absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source (IESNA). The colour temperature of the light source is measured in degrees Kelvin (K) and is a general measure of the ‘warmth’ or the ‘coolness’ of the emitted light. Light sources with a colour temperature below 3200 K are usually considered ‘warm’, while those above 4000 K are generally considered ‘cool’.

compact fluorescent light bulb (CFL) - a small fluorescent bulb, usually with one or more bends in the tube. These bulbs are operated by a magnetic or electronic ballast which is either incorporated with the bulb into a single unit (integral system) or is separate from the bulb (modular and dedicated systems).

current - a flow of electrical charge, measured in amperes or amps.

dedicated system - a CFL-ballast system where the ballast and socket for the CFL are permanently wired into the light fixture. The ballast may be located in the fixture or the wall plug.

dimmer - a device used to control the intensity of light from a luminaire by controlling the voltage or current available to it.

discharge light source - a light source which produces light by the passage of an electrical current through a vapour or gas.

efficacy - (of a light source) the total light output of a light source divided by the total bulb power input, expressed in lumens per watt. For fluorescent and high intensity discharge sources, the associated ballast wattage should be included in determining the system efficacy, as should any reductions in lumen output associated with the bulb-ballast combination.

efficiency - (of a luminaire) the ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the light source used therein (IESNA). Luminous efficiency expresses the percentage of initial light source lumens that are ultimately emitted by the luminaire.

electronic ballast - a ballast which uses electronic circuitry to provide the voltage and current needed to start and to operate the light bulb. Electronic ballasts weigh less than magnetic ballasts and operate more quietly. Electronic ballasts operate bulbs at a higher frequency (20,000-60,000 cycles per second) than magnetic ballasts (60 cycles per second) which eliminates flicker and increases efficacy.

EESOP (Energy Efficiency Standards of Performance) - the UK Public Electricity Supply companies (PESs) are required by the Electricity Regulator (OFFER) to spend the equivalent of £1 per customer per year, during the period 1994-98, on the more efficient use of electricity. This amounts to a total investment of £100 million, 25% of which was originally targeted at electrical appliances in the domestic sector. However, less has been spent in practice since insufficient schemes were forthcoming. Most of the investment to date has been on lighting.

ETP (Economic and technical potential) - ETP is technically feasible *and* cost-effective to the consumer. Cost effective means it is the minimum life cycle cost (See life cycle cost). Feasible means it is proven technology. Other assumptions are average usage patterns, current EU prices for electricity, water and equipment, average market mark-ups and an 8% discount rate. If energy or equipment prices change significantly, or if new technologies become available, then the ETP may change. It does not include any reduction in consumption from changes in behaviour and so does not represent the technical limit or the lowest limit on consumption.

EU (European Union) - The EU was established by the Maastricht treaty and comprises the European Community (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, United Kingdom, Austria, Finland and Sweden), a Foreign Defence and Security Co-operation Mechanism and a Home Affairs and Justice Co-operation Mechanism.

filament - a fine wire heated electrically to incandescence in an electric incandescent light bulb.

fitting - see fixture.

fixed luminaire - a luminaire which is wired directly into the electrical circuit of a house and is operated by a switch on the wall. These are usually ceiling or wall fixtures.

fixture - the part of the luminaire which connects the light source to the power supply and is designed to distribute the light and position and protect the bulbs.

fluorescent light bulb - a discharge light source containing mercury under low pressure. An electric arc ionises the mercury, generating ultraviolet energy which, in turn, excites the inner phosphorus coating of the light bulb to fluoresce and emit visible light.

GLS (General Lighting Service) bulb - see incandescent light bulb.

glare - the sensation produced by brightness within the visual field that is sufficiently greater than the brightness to which the eyes are adapted to cause annoyance, discomfort or loss in visual performance and visibility (IESNA).

halogen incandescent light bulb - see tungsten halogen light bulb.

halogen torchiere - see torchiere.

high intensity discharge (HID) light source - a group of electrical discharge lights which operate at relatively high pressures (compared to fluorescent lights) and includes mercury vapour, metal halide and high-pressure sodium light sources.

high pressure sodium light source - a high intensity discharge light source in which visible light is produced by radiation from sodium vapour under high pressure.

incandescent light bulb - a bulb which produces visible radiant energy by the electrical resistance heating of a filament (also known as a general lighting service bulb or GLS).

incandescence - the self-emission of radiant energy in the visible spectrum due to the thermal excitation of atoms or molecules.

indirect lighting - light arriving at a point or surface after reflection from one or more surfaces (usually walls and/or ceilings) that are not part of the luminaire.

integral ballast CFL - a single unit including the light bulb and the magnetic or electronic ballast. The ballast has a screw or bayonet base that fits into a standard incandescent socket.

integral system - see integral ballast CFL.

IEA (International Energy Agency) - independent organisation of 24 Member countries, established within the framework of OECD to carry out a comprehensive and co-operative development programme for sustainable international energy trade.

kW (kilowatt) - one thousand watts.

kWh (kilowatt-hour) - measure of electrical energy consumed. One kilowatt-hour is equal to one thousand watts used for one hour.

lamp - commonly used to refer to portable luminaires such as desk, floor and table lamps. ‘Lamp’ is used in the USA instead of light bulb.

life cycle cost - the cost of the appliance to the consumer over the lifetime of the appliance (ie running costs as well as purchase price).

light - radiant energy is capable of exciting the retina and producing a visual sensation. The visible portion of the electromagnetic spectrum - the region where radiation is absorbed by the photoreceptors of the human visual system - extends from about 380 to about 770 nm. Light cannot be seen directly. It must be reflected or transmitted by an object and interpreted by the brain as a visual image.

light bulb - a generic term for a manufactured light source (sometimes referred to as a lamp) which includes the bulb, the base, and the internal structure which produces the light, either a filament or an arc tube.

lighting system - the set of equipment used to produce light, which includes the luminaire and the control device.

light source - the object that produces the light - a light bulb for electrical lighting.

low voltage light bulb - a bulb that operates at a low voltage, such as 6, 12 or 24 volts. A transformer must be used to convert the 220-240V supply to the lower voltage.

lumen - SI unit of luminous flux and is the time rate of flow of light, which expresses the total light output of a light source. The lumen rating can be considered as a measure of the summation of light output of a bulb in all directions. Ratings are determined and published by the light source manufacturer.

luminaire - generic term for a complete lighting unit consisting of a light bulb(s), parts designed to distribute light, to position and protect the bulbs and to connect the bulb to the power supply.

magnetic ballast - a ballast which uses a magnetic coil and capacitor, designed to limit the current and provide the necessary voltage and current to start and to operate fluorescent light bulbs. Magnetic ballasts are heavier than electronic ballasts.

mercury vapour light source - a high intensity discharge light bulb in which radiation from mercury vapour under relatively high pressure produces visible light.

metal halide light source - a high intensity discharge light bulb in which radiation from a mixture of metallic vapour and halides (eg sodium, thallium) produces visible light.

modular system - a CFL-ballast system where a pin-based CFL plugs into a separate ballast unit with a screw or bayonet base and can therefore be used as a direct replacement for GLS bulbs.

MtC - million tonnes of carbon. The carbon dioxide molecule contains atoms of both carbon and oxygen, as shown by its chemical formula CO_2. The weight of a molecule of carbon dioxide includes both the elements of carbon (atomic weight of 12) and oxygen (each of the two atoms has a weight of 16), to give a total of 44. The present convention is to refer to the carbon content only, so that the weight of a molecule of carbon dioxide is expressed in terms of carbon alone. To convert to million tonnes of CO_2, multiply by 12/44.

pin base CFL - a CFL with a base having two or four pins that requires a different socket to the standard incandescent screw or bayonet sockets. A pin base CFL is used in modular and dedicated systems.

portable luminaire - a free-standing luminaire which plugs into an electrical socket and is operated by a switch on the cable or fixture itself.

Reference Case (RC) - a projection of usage and ownership and the underlying rate of technical change determined from historical data where available. This was formerly known as the Business as Usual (BAU) scenario in previous DECADE reports.

recessed luminaire - a luminaire that is mounted above the ceiling (or behind a wall or other surface) with the opening of the luminaire flush with the surface.

screw base CFL - a CFL with a ballast that has an Edison screw base that fits into the standard incandescent light bulb socket. A screw base CFL may be modular (see modular system) or self-ballasted (see integral ballast CFL). Both types are designed to replace standard incandescent light bulbs.

shade - a device on a luminaire used to prevent glare (by hiding the light source form direct view), control light distribution and sometimes to diffuse or colour the light emitted.

socket - the part of the luminaire which electrically connects the fixture to the light bulb.

spectral power distribution (SPD) - (of a light source) a pictorial representation of the radiant power emitted by a light source at each wavelength or band of wavelengths in the visible region of the electromagnetic spectrum (360 to 770 nm). The SPD curve illustrates the distribution of power produced by the light source, at each wavelength across the spectrum.

spot light - a light source that provides a relatively narrow beam of light (eg of angle 12° or less).

switch - a device that turns a luminaire on and off by completing or interrupting the power supplied to the luminaire(s).

table lamp - a portable luminaire with a short stand, suitable for standing on furniture.

task lighting - lighting that is directed to a specific surface or area. Task lighting provides illumination for visual tasks.

torchiere - a luminaire providing indirect light in an upwards direction lighter indirect, typically a floor-standing fixture, often installed with a high-wattage tungsten halogen bulb.

tungsten halogen light bulb - a type of incandescent light source with the tungsten filament enclosed in halogen gas which reacts with the tungsten evaporated from the filament to re-deposit it on the filament. Halogen incandescents have higher efficacies than common incandescent light bulbs. They are sometimes referred to as quartz bulbs because the envelope is made from quartz glass.

UEC (unit energy consumption) - average annual energy consumption per household for a specific end use, such as lighting.

uplighter - a luminaire that directs light upward onto the ceiling and upper walls of a room, eg a torchiere.

watt (W) - unit of active electrical power - a measure of the rate at which electrical energy is used.

watt-hour (Wh) - unit of electrical energy. One watt-hour is the amount of energy consumed at the rate of one watt during a one hour period.

wattage - the active electrical power consumed by a light bulb or other electrical device.

APPENDIX B: PROJECT MEMBER PROFILES

Dr Brenda Boardman (Energy and Environment Programme Leader)
Brenda is programme leader for the Energy and Environment Programme of the Environmental Change Unit at Oxford University. She has been PowerGen Fellow in Energy Efficiency at St Hilda's College, Oxford since October 1991. She specialises in the efficient use of energy in the UK domestic sector, in particular the policy implications and problems faced by low-income households. She is acknowledged as the leading UK researcher on fuel poverty, and is responsible for the concept of affordable warmth. She has published widely and is regularly called upon for expert contributions to conferences, specialist workshops and the UK media. In addition to managing the DECADE project (Domestic Energy and Carbon Dioxide Emissions), she has overall responsibility for the Programme's research for the European Commission and the Department of the Environment, Transport and the Regions, and for research on rural transport.

Harriet Griffin
Harriet has a background in Zoology and gained an MPhil from the University of St Andrews where she studied the role of wild bees in crop pollination. Before joining the ECU, where she contributes towards the analysis of trends in appliance ownership and use, she worked for the Agriculture Development Advisory Service.

Dr. Willi Herbert
Willi has been with the Research Association for Environmentally Sound Energy Conversion and Use Ltd. (RAESCU) *(oder: Forschungsgesellschaft für umweltschonende Energieumwandlung und -nutzung mbH)* as Senior Researcher and project manager since 1992 and is Head of the Unit for Energy Policy and Communication of the Energy Foundation *(oder: Energiestiftung)* Schleswig-Holstein since 1998. He has a background in Sociology, Political Science and Administrative Sciences. His actual main working fields are the development and evaluation of energy policy and energy policy instruments and the analysis of social and organisational determinants of energy consumption. He has published widely and is an invited speaker at national and international conferences.

Dr Mark Hinnells
Mark is responsible for analyses of technical trends in appliances and contributes to policy analysis for market transformation. He is leading the ECU's collaboration on efficiency of domestic electric storage water heaters and represented the ECU on the EU Group for Efficient Appliances study of washing machines, dishwashers and dryers. He has a background in Industrial Design with a Masters Degree from Manchester Metropolitan University and his PhD was on 'Evaluation of environmental impacts of domestic appliances and implications for public policy'.

Dr Kevin Lane
Kevin is responsible for developing the DECADE model, and applying it to policy analyses for EU working groups. He represented the ECU on the EU working group on standby consumption in televisions and videos and on the GEA 'wet' study. With a first degree in digital systems and microprocessor engineering, his doctoral research at Lancaster University was on the development and application of non-stationary time series analysis techniques to climatological data. His final project before joining the ECU was the development of the Derwent Water Resources Model (a computer based management model) for the National Rivers Authority. He was awarded jointly the World Meteorological Organisation's 1996 Norbert Gerbier Prize.

Susanne Lörx
Susanne has been with RAESCU as Researcher and Project Manager since 1993 and was in the same position with the Energy Foundation Schleswig-Holstein in 1998. She has a background in Social Sciences and Evaluation Research. She has done the evaluation of local energy conservation programmes including

the active participation of administration and inhabitants. She just finished (in collaboration with Kai Schuster) RAESECU's contribution to the evaluation (co-ordinated by the Wuppertal Institute) of the most recent and extended CFL campaign in Germany.

Dr. Tihomir Morovic

Tihomir has been Managing Director of RAESCU since 1990 and is Head of the Research Unit of the Energy Foundation Schleswig-Holstein since 1998. He has an Inauguration in Physics. He did a forecast on energy consumption up to 2010 and is an expert for the use of renewable energies. His actual main working fields include the analysis of the energy policy programmes in the Baltic region where he gained a lot of experiences with the execution of EC financed projects. He has published widely, is an invited speaker at national and international conferences and has been advisor to State Government and utilities on matters of energy conservation.

Jane Palmer

Jane graduated with an honours degree in Natural Sciences from Cambridge University and has a background in genetics. Jane joined the Energy and Environment team at the Environmental Change Unit, Oxford in July 1995 and worked on the analysis of ownership, stock profile and usage data for the DECADE model as well as being responsible for collecting and analysing the lighting data.

Agneta Persson (MSc)

Agneta is Head of Division of Energy Efficiency and Technology Procurement in the Domestic and Commercial Sector at the Swedish National Energy Administration. Agneta is one of the leading persons behind developing technology procurement in the field of energy efficiency. Agneta has also for many years been a keen mover towards energy efficiency in the domestic and commercial area, being the organiser and Conference Manager of the first European Conference on Energy-Efficient Lighting in 1991, and the ECEEE 1995 Summer Study. Her contribution has made these conferences, and networks to a valuable place for policy makers and energy efficiency researchers to meet. She holds a Masters Degree in Civil Engineering from Chalmers University of Technology, Gothenburg. She has published widely and is an invited speaker at national and international conferences.

John Rathbone

John has an MA in geography from Edinburgh University and is completing a DPhil thesis on the influence of weather on asthma admissions in the Oxford region. He has devised and taught an undergraduate course on database management and has lectured in geographical and epidemiological techniques.

Kai Schuster

Kai has been with RAESCU as Researcher and Project Manager since 1995 and is in the same position with the Energy Foundation Schleswig-Holstein since 1998. He has a background in Ecological and Motivational Psychology and Social Marketing. His current interests are the human aspects of energy use and the organisation of local climate protection policy. He just finished (in collaboration with Susanne Lörx) RAESECU's contribution to the evaluation of the most recent and extended CFL campaign in Germany.

Heini-Marja Suvilehto (BA)

Heini-Marja joined the Swedish National Energy Administration in 1994 as a member of the team developing the Effect Chain Analysis Method (a new, radically more reliable method for assessing market transformation actions and measures). She has performed analysis and in-depth studies of the potentials and dissemination of energy efficiency measures. Heini-Marja holds a Bachelors Degree in Political Economy from the University of Stockholm. She has participated in several international projects on improving data on energy efficiency.

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