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BARRIERS TO TECHNOLOGY DIFFUSION: THE CASE OF COMPACT FLUORESCENT LAMPS

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FOREWORD

This document was prepared by the OECD and IEA Secretariats in September-October 2006 in response to the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy-makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

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Executive Summary

Artificial light production accounts for 8.9% of total global primary consumption and represents approximately 8% of world CO₂ emissions. Improving the efficacy of lighting systems can therefore be an important means to lower greenhouse gas emissions.

The efficacy of lighting systems vary significantly from sector to sector, ranging from as low as 20 Lumens/Watt (lm/W)¹ in the residential sector to as high as 80 lm/W in the industrial sector. From a technological perspective, the low efficacy achieved in the residential sector is to a large extent due to the important role of incandescent lamps, which are characterised by very low energy efficiency.

Substituting incandescent lamps with Compact Fluorescent Lamps (CFLs) can therefore be an effective means to improve residential sector lighting efficacy as they consume 1/4th to 1/5th of the energy used by incandescent light bulbs to provide the same level of light.

While CFLs have a higher initial cost, due to their low energy use, on a life cycle basis they are significantly more economical than incandescent lamps. CFLs therefore offer a win-win-win alternative with climate, economic, and - to the extent that their use displaces the consumption of risk-prone fossil fuels and reduces system load - energy security benefits.

Yet CFLs only account for 6% of the lighting market and represent a minor share of light production in the residential sector. The natural uptake of CFLs in the market is hampered by a variety of barriers. Though CFL costs have gone down significantly since they were first introduced, their high initial cost compared to incandescent lamps remains an important barrier particularly for the poorer sections of the community.

Coupled to this, early CFLs have had a number of quality and suitability issues to address. First generation CFLs were only available in cooler light colours, and had a tendency to flicker. Their magnetic ballasts were prone to delays when starting up, and their shapes were generally inadequate for traditional house fittings. Although most of these shortcomings have been resolved, early generation CFLs have created some consumer distrust in the technology.

Moreover, incomplete information in the lighting market and the difficulty of altering consumer habits are further obstacles to CFL diffusion.

To capture the benefits of CFLs, governments can implement policies and measures to overcome such barriers. A number of countries already have experience with such programmes. The cases of Brazil, California, China, South Africa and the United Kingdom are considered here to draw lessons from this experience and to help improve the design of future CFL and other technology diffusion programs. These case studies focus on actions that displace incandescent lamps in favour of CFLs, which is where the major savings opportunity lies.

The programmes in each considered case study were implemented for different reasons - climate change mitigation, energy security, or industrial development. The policy context, however, influences the types of measures adopted and determines the level of support within and outside of government. Governments should therefore not focus on one of the attributes of CFLs diffusion but rather emphasise the multiple benefits – in terms of security, climate and economics – of CFL programmes to broaden and deepen their political foundation.

While barriers to CFL diffusion exist in all countries, their magnitudes vary depending on the country and its socioeconomic conditions. CFL penetration in advanced developing countries such as Brazil and China is

¹ The light output of a light source is measured in terms of its “luminous flux”, with units in lumens [lm]. This is the total light output of the source in all directions. The efficacy of the light source is the ratio of the lumens emitted per watt of power consumed.

notably much higher than in most – if not all – OECD countries. While policy programmes have contributed to this success, this reflects more profound differences between OECD and less developed countries. For example, due to the extensive experience with incandescent lamps, shifting away from this technology seems more difficult in OECD countries than in developing countries where such technological path dependency is more limited.

It is therefore important for a country wanting to set up a policy programme to enhance CFL diffusion to clearly identify the barriers specific to their country's socio-economic circumstances in order to optimise policy choices.

A number of policy-specific lessons can be drawn from the cases considered. First, lowering the price differential of CFLs compared to incandescent lamps through, for example, a subsidy programme is effective in supporting market growth and provides a strong foundation to demonstrate long-term CFL benefits. Second, promotional campaigns can be effective though they require a high level of coordinated involvement from all actors in the lighting market. Third, ensuring the quality of CFLs through certification schemes can also contribute to build trust in the technology.

The case studies show that success was partly conditional on policy addressing multiple barriers. The first cost and information barriers were most often addressed jointly. Yet other barriers should also be addressed. Governments should emphasise the need for a portfolio approach with different measures targeting different barriers.

Also, to provide consistent messages, programmes need to be sustained and adjusted as the CFL market evolves. A monitoring and evaluation process to gauge the effectiveness of measures should be included in any CFL diffusion programme.

In sum, policy tools exist to effectively accelerate the penetration of CFLs. More ambitious approaches than reviewed here may also be considered. The complete phase-out of incandescent lamps may notably constitute an achievable policy objective. Governments may notably consider collaborating to define an international agreement to phase out incandescent lamps. Governments may further wish to use the case of CFLs to push for more CDM projects targeting energy efficiency.

1. Introduction

In 2003, the provision of artificial light was estimated to result in the consumption of approximately 650 Mtoe of primary energy, which represented 8.9% of total global primary energy consumption. As a result, globally, lighting-related CO₂ emissions are estimated at 1,900 Mt CO₂, equivalent to approximately 8% of world emissions, or 14% of Annex-I emissions.²

From a climate policy perspective therefore, reducing lighting energy consumption by raising the efficacy of lighting systems can be an important means of CO₂ abatement. The higher the efficacy, the lower the energy required to deliver a given amount of light, and – depending on the carbon intensity of the electricity generation fuel mix – the lower the greenhouse-gas emissions.

The average lighting system efficacy has increased significantly over the past decades. In 1960 the global average lighting system had an efficacy of about 18 lm/W, whereas by 2005 this had risen to roughly 50 lm/W. Lighting efficacy, however, is not uniform across all lighting applications as much depends on human needs and technological choices. On average, the residential sector has by far the lowest lighting efficacy estimated at only slightly above 20 lm/W in 2005. This is much lower than the efficacy levels of other sectors such as the commercial sector, estimated at slightly above 50 lm/W, or the industrial sector, at about 80 lm/W.

The low lighting efficacy in the residential sector, and to a lesser extent in the commercial sector, cannot be attributed to a single factor. In addition, circumstances vary from country to country. Yet from a technology perspective, the penetration of incandescent lamps, which are characterised by very low efficacy levels compared to other lighting technologies, is an important contributor to the low sectoral efficacy levels achieved. As can be seen in figure 1, incandescent lamps account for close to half of the residential sector light production and a little above 5% of the commercial sector light production. In contrast incandescent lamps account for only a negligible share of light production in the industrial sector and of outdoor stationary lighting. Substituting conventional incandescent light bulbs with more efficient alternatives, therefore, can constitute an important means to improve these sectors' lighting efficacy.

The Compact Fluorescent Lamps (CFL) with integrated ballast³ was developed as an alternative to the incandescent light bulb specifically for this purpose. CFLs consume a 1/4th to 1/5th of the energy used by incandescent light bulbs to provide the same level of light. About 25% of energy consumed by CFLs is converted to visible light compared with just 5% for a conventional incandescent lamp. CFLs also have much longer lifetimes with rated life spans of 5,000 to 25,000 hours compared to 1,000 hours on average for incandescent lamps.⁴

Globally incandescent lamps are estimated to have accounted for 970 TWh of final electricity consumption in 2005 and given rise to about 560 Mt of CO₂ emissions. About 61% of this demand was in the residential sector with most of the rest in commercial and public buildings. If current trends continue incandescent lamps could use 1610 TWh of final electricity by 2030. In the hypothetical case that all these lamps were to be replaced by CFLs it would save roughly 800 TWh and 470 MtCO₂ emissions in 2010 rising to 1200 TWh and 700 MtCO₂ in 2030.

² When not referenced otherwise, figures quoted in this paper are from a recent IEA (2006) publication: *Light's Labour's Lost*.

³ Fluorescent lamps, like other discharge lamps (e.g. low pressure sodium lamps) require a ballast to function. Ballasts are devices that supply a high voltage to initiate a discharge arc and then limit the current to stabilise the discharge arc during normal operation. As mentioned in Annex, the ballast can either be integrated to the CFL or separate.

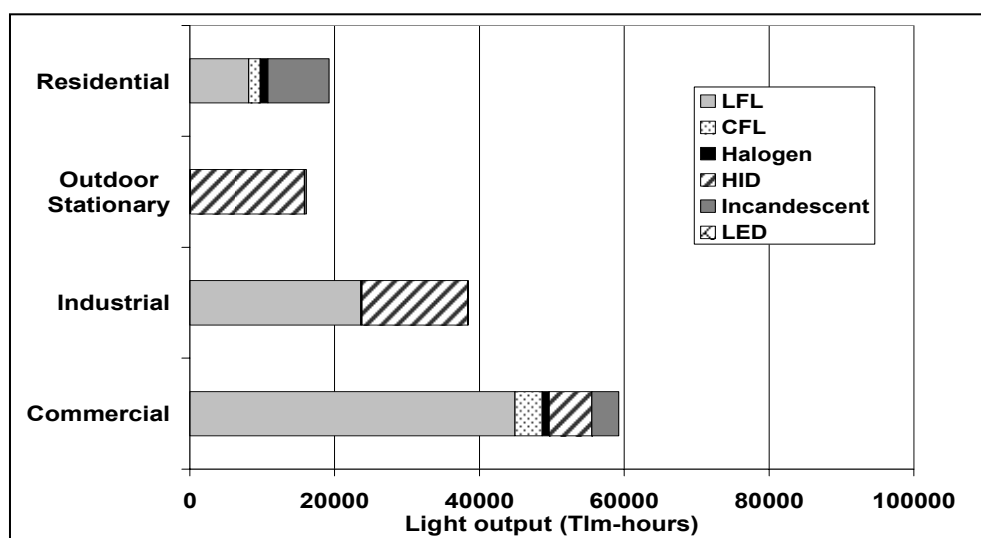
⁴ A more detailed account of both incandescent lamp and CFL technologies is provided in annex to this paper.

As discussed in the next section, on a life cycle basis, the use of CFLs is also more economical than that of incandescent lamps. The adoption of CFLs in place of incandescent lamps therefore seems to offer a win-win situation with benefits from a climate perspective, an economic perspective, and - to the extent that the adoption of CFLs reduces system load and/or the consumption of primary fuels exposed to international market risks - from an energy security perspective.

Yet barriers have nevertheless hampered the broad diffusion of CFLs. As seen in figure 1, as of 2005 CFLs only account for a fraction of light production in the residential sector and for approximately the same level of light production as incandescent lamps in the commercial sector. In the scope of energy efficiency policy, many governments are therefore devising measures to overcome key barriers to the broad diffusion of CFLs as substitutes to incandescent lamps. This paper reviews a number of such efforts and intends to draw lessons from this experience to help improve the design of future CFL and other technology diffusion programs.

The next section will first describe the state of CFL and incandescent lamp markets. Section 3 will then give an overview of the main barriers which have, and continue to hamper CFL technology diffusion. Section 4 will then describe a number of country case studies where policy programmes have been devised to overcome some of the barriers discussed in section 2 to enhance CFL technology diffusion in place of incandescent lamps. Finally, section 5 will discuss lessons learned from these case studies and conclude.

Figure 1: Estimated light production by user sector and lamp type and (2005)



Note: LFL = Linear Fluorescent Lamps; HID = High-Intensity Discharge Lamps; LED = Light-Emitting Diodes. Source: IEA (2006).

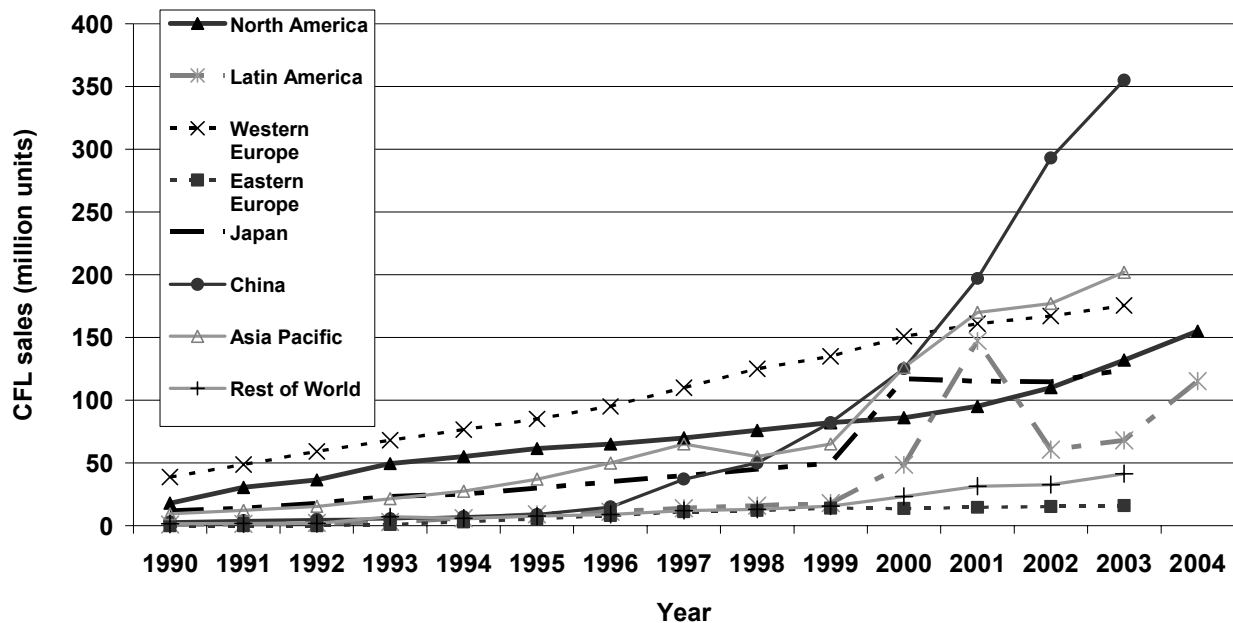
2. An Overview of CFL and Incandescent Lamp Markets

2.1 Lamp sales by volume

Statistics on global lamp sales are hard to come by. The IEA (2006) has therefore recently reviewed a large number of sources to produce an estimate of lamp sales by country. As expected, incandescent lamps are by far the most commonly sold lamps in the world. They dominate retail lamp sales oriented towards residential sector in most countries. It is estimated that roughly 13.2 billion units were sold in 2003 representing over 72% of the global lamp market by volume that year. The United States and China are the largest markets for incandescent lamps, with sales in excess of 2.5 billion lamps in each market. Sales in the rest of Asia and Former Soviet Union countries are estimated at 3.2 billion units and in Europe at about 1.8 billion.

In contrast, CFLs sales in 2003 are estimated at 1.1 billion units, representing approximately 6% of the global lighting market by volume. Looking back at sales since their introduction in the early 1980s is, however, indicative of future sales trajectories. Figure 2 shows estimated global sales figures by region between 1990 and 2004. CFL sales have slowly increased over much of the 1990s and rose sharply starting from 1999. Europe was the largest market for CFLs until 2001, but thereafter China has become the largest market. CFL sales in 2003 in China are estimated at 355 million units, representing over 30% of the global market.

Figure 2: Estimated global CFL sales by region, 1990-2004



Source: IEA (2006)

The market share by volume of CFLs varies greatly from country to country. In the United States, CFLs accounted for close to 3% of medium screw-based lamps in 2004 while in Europe CFL sales comprise 10% of incandescent lamp sales. In Japan sales slightly exceed those of conventional incandescent lamps. This, however, is mostly a reflection of low incandescent lamp sales as the Japanese household lighting market is dominated by linear fluorescent lamps. This holds true in some other Asian countries such as the Philippines where linear fluorescent lamps play an important role in households. Many other developing countries also have high CFL penetration rates. In China for example, it is estimated that CFL sales reached close to 14% of incandescent lamp sales in 2002.

2.2 Penetration⁵ in the residential market

CFL sales are driven by the rise in diffusion in the residential market. The number of CFLs per household appears to be growing in the OECD, albeit at a moderate rate. A review of CFL ownership across the OECD in 1999 (Kofod) estimated that there was an average of 0.8 CFLs per household, with ownership levels ranging from just 0.1 CFL per household in OECD Australasia and North America, rising to levels of approximately 1.5 CFL per household on average in OECD Europe. In the USA average CFL ownership had risen to 0.7 lamps per household by 2001 and today it is likely to be higher still as average annual sales

⁵ The term penetration is used here to refer to the number of installed units in households. It does not necessarily reflect use. This is particularly important in the case of CFLs as there is some evidence that CFLs are often used in lamp sockets with higher than average hours of use and therefore may account for a greater share of total lighting provision. This of course is likely to change as penetration increases and CFLs are used in other lamp sockets.

growth rates of 19% are reported for the 2001–2004 period (Nadel et al., 2005). In the United Kingdom, CFL ownership rose from 0.7 lamps per household in the late 1990s to about 2 in 2005 (DEFRA, 2005). In Denmark (EURECO, 2002), ownership increased from 2.4 to about 3.6 in 2002.

CFL ownership as a proportion of total installed residential lighting is sometimes significantly higher in non-OECD countries. In China, of an average of 6.7 lamps per household, 1.5 (23%) were reported to be CFLs in 2003 (ACMR, 2004). In Brazil, precise ownership figures are not available, but CFL sales averaged 24% of incandescent lamp sales by volume from 2000 to 2004 (Januzzi, 2005b). If it is assumed that 90% of the incandescent lamps and 75% of the CFLs were destined for the residential sector and that the average CFL lasts six times as long as the average incandescent lamp, by the end of 2004 there should be about as many CFLs per household as incandescent lamps on average (IEA, 2006).

3. Common Barriers to CFL Technology Diffusion

Before describing various policy programmes which have been implemented around the globe to enhance CFL technology diffusion it is useful to first review the main barriers which hamper the natural uptake of CFLs in residential and other lighting markets. This brief overview classifies barriers to CFL technology diffusion into three groups. Those linked to cost and technological properties, those inherent to the organisation of the lighting sector, and finally those linked to behavioural or consumer preferences. Each is discussed below.

3.1 Cost and technological barriers to the diffusion of CFLs

Historically, the largest barrier to the deployment of CFLs has been their high initial cost. When first launched in the early 1980s, CFLs were 20 to 30 times more expensive to produce than their incandescent equivalents. CFL costs have since steadily declined through deployment and increased competition and now retail for as little as four times the price of an incandescent lamp.

Table 1 shows life cycle cost to an end user of both incandescent lamps and CFLs. The cost assumptions adopted in this exercise are conservative. In reality, costs (and in particular that of CFLs) will vary depending on where the lamp is produced. It shows that even when considering an initial cost 20 times higher than that of incandescent lamps, when energy costs are included CFLs cost less than a third of the cost of incandescent lamps.

This simple analysis does not take into account the impact of displaced heat. As noted in the introduction about 25% of energy consumed by CFLs is converted to visible light compared with just 5% for a conventional incandescent lamp. This means that 75% of input energy is output heat in the case of CFLs compared to 95% in the case of incandescent lamps. In some circumstances and in particular cold climates the introduction of CFLs in place of incandescent lamps may, therefore, lead to greater heat demand with associated costs. In warmer climates, however, CFLs may displace demand for air-conditioning reducing cooling costs. The financial impact is therefore highly dependent on the climate and on heating fuel used. Globally, significantly more electricity networks are summer peaking in response to air conditioning demands than are winter peaking due to space heating where non-electric commercial fuels usually dominate. Thus overall, the high correlation between air-conditioning and peak electricity demand will most likely give a greater global weight to the additional benefits of lowering air-conditioning demand than the increase in space heating energy needs.

Table 1: The economics of CFLs compared to incandescent lamps

	<i>Incandescent lamp</i>	<i>CFL</i>
Initial cost of bulb (USD)	0.50	10
Light output (lm)	900	900
Lamp power (W)	75	15
Efficacy (lm/W)	12	60
Lifespan of bulb (h)	1000	10 000
<i>Calculation over a 10 000h operating period, assuming an electricity tariff of USD 0.1/KWh</i>		
Electricity consumption (kWh)	750	150
Cost of electricity (USD)	75	15
Cost of lamps (USD)	5	10
Total cost of lamp and electricity (USD)	80	25
Total savings for CFL (USD)		55

Source: IEA (2006)

While as shown above on a life cycle basis CFLs are far more economical than incandescent lamps⁶, the higher initial cost remains an important barrier to the broad diffusion of CFLs. Incandescent bulbs are the dominant technology in most countries to a large extent because they are so cheap. On the one hand, higher income consumers often regard incandescent lamps as disposable. In this case therefore, the higher initial cost/lower life cycle cost characteristic of CFLs is a market barrier because of incomplete or inaccurate consumer awareness about the competing technologies and limited confidence in the new technology. These issues are addressed in the subsections below. On the other hand, for the poorer sections of the community the capital cost of CFLs can be a substantial barrier even if they save money in the end. Many will always opt for the cheapest option if there is a price differentiation. In this case, the higher initial cost of CFLs is a purely financial barrier.

In parallel to high costs, early CFLs, while compact when compared with tubular fluorescent lamps, were still more bulky than the incandescent lamps they were designed to displace. With most residential light fittings having been designed over many decades to fit the highly standardised dimensions of incandescent bulbs, the additional length and bulk of CFLs acted as a significant disincentive for residential buyers. CFLs have also had a number of quality and suitability issues to address. The first CFLs had limited colour ranges and tended to only be available in the higher cooler-light values. CFLs using magnetic ballasts were also prone to delayed starts and long warm-up times and could suffer from flicker.

Market driven improvements, accompanied by various market transformation efforts have to a large extent addressed these technical issues. The size of CFLs has been significantly reduced. There are now also a far greater range of sizes and shapes available on the market. Current generations are available in the same warm colours provided by incandescent lamps. In addition, the introduction of higher quality lamps using electronic ballasts has overcome much of the delayed-start and flicker problems.

3.2 Organisation of the lighting market and its impact on CFL diffusion

As in any market, the availability of accurate and complete information is a necessary element to ensure the effective allocation of resources. Energy efficient lighting systems cover a wide range of technologies and it

⁶ Even in this example where rather high CFL costs are assumed, a CFL that displaces an incandescent lamp represents an investment with an internal rate of return of over 180%!

is difficult for consumers, and even distributors and installers, to learn about all their attributes, including quality. The comparatively high running costs of incandescent bulbs are, for example, often poorly understood. Most consumers receive electricity bills infrequently and have no way of understanding which part of the bill is accounted for by lighting. Information is also often not readily available at the point of sale, making it all the more complicated for consumers to make informed choices. Lack of information hampers the decision making process and often leads consumers to prefer known technologies.

Another important characteristic of the lighting market is that generally, those making decisions about lighting equipment are not the ones who pay directly for the system's energy use and hence lack an incentive to minimise operating costs. Indeed, when a developer or landlord is constructing or retrofitting a building they may have every incentive to lower initial costs, including by installing less efficient lighting systems. The tenant or purchaser of the building is then obliged to pay for the operating and maintenance costs associated with the chosen system. In the case of CFLs, they can be used as substitutes to most types of incandescent bulbs. So a tenant or purchaser can often easily choose to replace an incandescent bulb with a CFL if that is the system installed. Yet CFLs cannot replace all incandescent lamp types. In some cases the tenant or purchaser is therefore bound to the less efficient technology. In addition, in many commercial buildings tenants hire a managing company to take care of the building including of lighting systems. Depending on the maintenance contract, the managing company may have little incentive to replace the incandescent lamps with CFLs.

Another important aspect specific to residential lighting is linked to the purchase of lighting equipment. Light bulbs and lamps suitable for residential applications are readily available in a wide range of retail outlets, ranging from grocery stores, corner stores, large department stores and specialty lighting stores, to appliance or building-supply stores. However, the EU's Atlas project⁷ estimates that 40% of all general lighting sources are purchased from supermarkets. CFLs are beginning to be displayed more prominently in retail outlets, including supermarkets, although still much less so than incandescent bulbs.

Another important characteristic of the residential lighting sector is that movable lamps are typically an important component of total lighting use in the residential sector. For this reason, unlike in the commercial and industrial building sector, building energy codes rarely prescribe maximum lighting energy requirements for residential housing.⁸ Decisions about lighting are therefore made without regulatory guidance on energy efficiency.

3.3 Behavioural and consumer preferences and their impact on CFL diffusion

Most users are time constrained and have to balance benefits of optimising decision making about lighting efficiency with many other competing demands on their time. Given the need to prioritise, many will choose to invest their efforts in other directions and live the consequences of poorly informed decisions about lighting.

Consumers are also sceptical about predictions of the benefits of any new technology, and this holds equally true for energy-efficient lighting. Many consumers are concerned that CFLs lack performance and reliability. In addition, some early models were substandard and bad reports quickly travelled from consumer to consumer. Many manufacturers also promoted CFLs on the basis of their length of life and therefore consumer expected every lamp to meet the lifetime statement – however in fact this only refers to the average lifetime. Some fail early, thereby disappointing consumers. Like many energy efficiency technology, consumers who have had a bad experience tend to be shy of CFLs even though many of the early problems have been reduced significantly. Consumers often look for guarantees or assurances that the products they buy will achieve the promised results, especially when they have paid a high initial cost compared to prices for other, less efficient products.

⁷ www.europa.eu.int/comm/energy_transport/atlas

⁸ The UK is the only IEA country to prescribe maximum lighting energy requirements in the residential sector. California also imposes requirements.

In addition, consumers normally opt to avoid changing habits or actions, especially when conditions such as energy prices are stable. Even given rapid economic changes as has been evident in transition countries in Central and Eastern Europe, there is often a reluctance to move from known practice, even if purchasing energy-efficient lighting makes financial sense.

Lighting energy demand in the residential sector is also affected by occupancy patterns and lifestyle factors. In living rooms, people generally like to be able to dim lights. Similarly, people often appreciate mood lighting, in which case warm colour tints (yellow, orange) are often preferred. CFLs most commonly sold on the commercial market were generally not dimmable and tended to be of blue, white colour. Modern CFLs are now increasingly dimmable and available in a broad range of colour temperatures yet as mentioned above, it may be that consumers have been 'turned off' by earlier models.

In addition, a significant trend in many OECD countries, consistent with the wider trend towards investment in home decorating, is to install spot-lighting (for architectural features or art-works) systems. These systems may lead to a greater number of lamps per home and also to a preference for less efficient lighting types (such as low-voltage halogens for spot-lighting and dimmable high-voltage halogens or incandescent lamps for mood lighting).

4. Case Studies: Policies and Measures to Enhance CFL Diffusion

The CFL market has evolved dramatically over the past two decades. Prices have fallen and acceptance has increased. Market dynamics have played a key role in the growing CFL market share. Competition between producers has notably been fierce and is now increasingly international. Yet government policies and programmes targeted at overcoming some of the barriers discussed above have also played an important role in achieving increasing CFL penetration rates.

Many countries have implemented policies and measures to promote CFLs and there are a number of ways to describe and discuss these. We have chosen to privilege in this paper the description of entire policy programmes at the country or - in the case of California - the state level. In doing so the objective was to clearly link the policy context to the policies and measures defined as well as to give a time perspective. Five case studies of programmes designed to enhance CFL penetration are considered: that of the Brazil, California, China, South Africa and the UK. In each case the policy context in which the CFL diffusion programs have been implemented is discussed before giving an overview of the policies and measures defined based on available information. This is then followed by a brief impact assessment.

4.1 Brazil

Context

Electricity demand in Brazil grew, on average, by 4.2% between 1990 and 2000, driven by strong economic growth. It dropped by 6.7% in 2001 due to significant power shortages before growing again between 2002 and 2004 at an average rate of 5.2%.

Hydroelectric power represents approximately 80% of Brazil's power generation capacity and, depending on the year, up to 90% of power generation. Brazil has some of the world's largest dams but reservoir capacity is relatively small. As a result, reserves are rapidly affected by changes in rain conditions. In 2000 and 2001, due to particularly low rainfalls, reservoirs dropped to as low as 18% of capacity in dams in the south of the country and 5% of capacity in the drier Northwest (Gall, 2002) leading to severe supply security concerns and the adoption of stringent demand curtailment measures.

Policies and measures

While the rainfalls were certainly exceptionally low, generation capacity additions have also lagged behind the rapid growth in electricity demand that occurred during the 1990s (IAEA, 2004) putting additional pressure on existing capacity. To some extent, this can be attributed to the uncertain regulatory environment created by the transition to a liberalisation market model, initiated in the 1990s and which led to significant privatisations in the electricity sector. The relatively limited flow of new investments in generation capacity has led utilities to draw extensively on existing dam reservoir capacity (Gall, 2002).

In 1985, the government of Brazil defined a National Electricity Conservation Programme, known as PROCEL, to promote end-use electricity conservation and transmission and distribution loss reduction. PROCEL funds or co-funds projects implemented by distribution utilities, state agencies, private companies, industry associations, and municipalities, or universities and research centres. PROCEL also helps utilities obtain low-interest loans for major energy efficiency projects.

The promotion of CFLs is one of the components of PROCEL's portfolio of activities. CFL projects have included co-funding of demonstration programmes, education projects and general promotional activities, including TV advertisement, to raise consumer awareness. PROCEL has also worked with utilities to define and co-finance a number of incentive programmes to encourage the purchase of CFLs, and in poor areas undertaken free distribution operations. These have allowed utilities and the government to gain experience with the administration of rebate and give away schemes.

In 1993, PROCEL introduced a voluntary endorsement label (Selo PROCEL or SEAL) to indicate the most energy efficient CFL models in conjunction with the Energy Conservation Label (ECL) which provides consumer information. The best rated CFLs with the ECL label are attributed the Selo PROCEL high quality stamp. The main quality standards needed to obtain the labels are shown in table 2. Testing to obtain the Selo PROCEL stamp is undertaken by authorised testing laboratories (paid by manufacturers).

Table 2: SEAL and ECL quality requirements

		Rated Power Input	ECL	SEAL
Energy efficiency	Bare-tube	<15 W	≥40 lm/W	≥45 lm/W
		≥15W	≥40 lm/W	≥60 lm/W
	With translucent cover	<15 W	≥40 lm/W	≥40 lm/W
		15-18 W	≥40 lm/W	≥48 lm/W
		19-24 W	≥40 lm/W	≥50 lm/W
		≥25 W	≥40 lm/W	≥55 lm/W
Rated life	Maximum 1 failure in 10 bulbs in 2000 hours			

Source: Fridley et al. (2005)

In 1998, the new electricity sector regulatory agency (known as ANEEL) issued a resolution mandating all distribution utilities to spend at least 1% of revenues on energy efficiency improvements.⁹ Utilities were initially responsible for formulating and implementing the programmes, which led them to favour investments on their own operations rather than in end-use energy efficiency. In 2000, the law was changed. From then on half of the 1% obligation was spent directly by the utilities (under ANEEL oversight) while the other half was spent by a specific energy efficiency and energy R&D fund set up by the government. The utilities' share could only be used to implement end-use efficiency programmes. From 2006 however, the law states that only half of the utilities share had to be spent on end-use efficiency (Jannuzzi, 2005, Jannuzzi

⁹ ANEEL resolution 242/98

et al., 2006). In 2002 ANEEL required that all equipment purchased in utilities' energy efficiency programmes had to bare the Selo PROCEL label.

In May 2001, the prospects of potentially long-lasting electricity blackouts due to the exceptionally low hydropower reserves led the government to adopt a stringent temporary demand curtailment strategy for nine months during 2001-2002. The government formed a special electricity crisis management commission directly linked to the presidency to coordinate the strategy. It defined a programme around three axes:

- Electricity rationing

This involves mandatory energy savings for all consumers, aiming at reducing national power consumption by 20%. Targets are differentiated according to demand segment. Households consuming over 100 kWh per month were required to reduce their electricity use by 20% relative to consumption in the previous year. No restrictions were imposed on households consuming less than 100 kWh. Depending on the sector, businesses were required to reduce electricity consumption by between 15% and 25% compared to previous year values while street lighting had 35% saving target. Penalties and incentives were introduced to promote the reduction in demand with the threat of disconnection for certain consumers. A bonus of one Brazilian *Real* was offered for each KWh saved in excess of the quota for low demand consumers.

- Nationwide public awareness of the crisis

Utilities and the federal government initiated an intense information campaign in all media on how to save electricity. Energy saving alerts were shown on television to promote consumer awareness of the results of saving efforts.

- Utility rebate

Government purchase 5.6 million CFLs for distribution to poor people. This was undertaken as part of the ANEEL investment obligation.

In June 2006, the government of Brazil enacted mandatory minimum energy performance standards¹⁰ for CFLs (both produced in, and imported to Brazil) – details shown in table 3 below. The new regulation also specifies that basic efficiency of the CFL must be clearly indicated on the wrapping of the CFL. The National Institute for Metering, Normalisation and Industrial Quality (INMETRO) is responsible for the implementation of the minimum standard. Before commercialisation of new models, domestic manufactures and importers must seek authorisation after having their products tested in registered laboratories.

¹⁰ Portaria Interministerial #132, de 12 de Junho de 2006.

Table 3: New minimum energy performance standard for CFLs sold in Brazil

Bare CFL	Minimum energy efficiency (lumen/Watt)
rated power \leq 8W	43
8W < rated power < 15W	50
15W < rated power < 25W	55
25W < rated power	57
CFL with transparent or translucent cover	Minimum energy efficiency (lumen/Watt)
rated power \leq 8W	40
8W < rated power < 15W	40
15W < rated power < 25W	44
25W < rated power	45

Source: Portaria Interministerial (2006)

Impact assessment

Before assessing the impact of the Brazilian programmes on CFL technology diffusion it is useful to note that in general, electricity prices in Brazil increased during the 1997-2004 period. This, coupled with declining average incomes following the economic downturn of the 1990s, no doubt increased consumer interest in energy efficiency. However, the importance of this factor remains uncertain (Souza et al., 2005).

While in a 1999 assessment, PROCEL (1999; Geller, 1999) considers that 35% of 1998 CFL sales (estimated at approximately 8 Million units) can be attributed to its programmes, it is difficult to assess PROCEL programmes in detail. It seems certain however that through its cooperation with utilities, much experience has been gained with the management of CFL promotion programmes such as rebates and distribution schemes, as well as information dissemination campaigns.

Probably the most successful CFL program undertaken by PROCEL is its labelling scheme. Through both the implementation of the ECL label and the Selo PROCEL quality stamp, PROCEL has helped to coordinate the setting up of testing laboratories. It has also increased the dissemination of high quality CFLs thanks to the purchase of stamped CFLs by utilities under their energy efficiency investment obligation, and enhanced public awareness. Unfortunately however, it seems the underlying standards used to rate CFL quality are not being upgraded in parallel to quality improvements. The market is therefore increasingly saturated with Selo PROCEL models, jeopardizing the credibility of the scheme.

The mandatory energy efficiency investment obligation put on electricity distribution utilities has mobilised significant funds, averaging at US\$57 million per year during 1998-2004. The share spent on end-use efficiency grew from 32% in 1998 to 100% from 2002 (Jannuzzi, 2005).¹¹ Before 2001, virtually none of the investments mobilised through the utility obligation targeted CFL diffusion. Improving public lighting (mainly through changing incandescent lamps for mercury vapour and mercury for sodium high pressure lamps) has, by far, been the most important end-use application, accounting in general for between 50% and 70% of total end use efficiency investments available. Residential sector funding was, however, exceptionally important over the 2000/2001 period – representing over 55% of total funding that year – due to the mandatory electricity demand curtailment measures in place. The replacement of incandescent light bulbs by CFLs was the most important component of residential sector measures.

¹¹ In comparison, total PROCEL investments are estimated at US\$ 14 million on average during 1994-2003

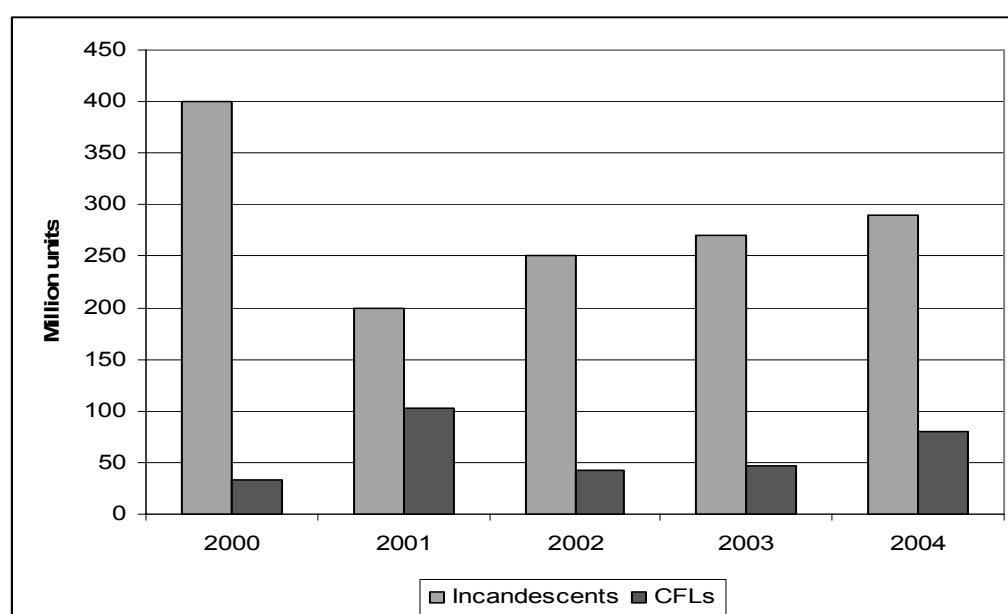
Overall, the demand curtailment measures put in place in 2001 were successful in curbing demand and avoiding blackouts. In the process, public awareness with regards to energy efficiency grew significantly. CFL sales in 2001 more than tripled compared to 2000, contributing in shaving residential lighting load.

More precise information on recent consumer patterns with regards to electrical goods and how the various programmes - including the 2001 power crisis management scheme - have influenced these are unfortunately not common in Brazil. In response to this PROCEL and the Energy Institute of the Catholic University of Rio de Janeiro (IEPUC) launched in 2004 a nationwide survey of household appliance saturation, energy conservation and measures and practices. Souza and Geller (2005) assess survey results for Rio de Janeiro and provide useful insights with respect to CFL penetration.¹² In particular, they highlight a dramatic decline in the use of incandescent lamps in households in Rio de Janeiro, particularly during the 2001 rationing exercise. Between 2002 and 2004, however, the use of incandescent lamps was found to have stayed constant. They note: “the penetration of CFLs increased dramatically between 1999 and 2002. Households in Rio de Janeiro now have nearly 2.3 CFLs (...) and 4.5 incandescent lamps on average”.

Interestingly, the study notes that when asked in 2002 about intentions to permanently use CFLs, most households said they intended to do so. However, CFL penetration did not increase in Rio de Janeiro between 2002 and 2004. The first cost premium was certainly a factor affecting this trend. Indeed, CFLs cost R\$10-15 in Brazil as of 2004-2005 compared to \$R1 for a 60-Watt incandescent lamp¹³ (Souza et al., 2005).

Looking at estimates of total sales of incandescent and CFLs in Brazil since 2000 does nevertheless provide some insights as to the diffusion of CFLs at the country level (figure 3). Over the 2000-2004 period CFL sales accounted for 1/5 of incandescent sales. Assuming CFLs last on average 6 times as long as conventional incandescent lamps, CFLs would now account for about half of the installed screw-based lamp stock in Brazil (IEA, 2006), suggesting the country has one of the highest CFL penetration levels in the world.

Figure 3: Incandescent and CFL sales in Brazil



Note: Data from Jannuzzi (2005b)

¹² Nationwide results were not available at the time of writing

¹³ The exchange rate was approximately R\$2.70 per US\$ in early 2005)

4.2 California

Context

California's electricity demand increased by 23% percent between 1995 and 2005, supplied through in-state capacity additions as well as through growing imports from neighbouring states. In 2005, the State of California generated 78% of its electricity needs and imported the rest.

California was among the first US states to implement energy efficiency measures. In 1974 it created a state agency—now the California Energy Commission—with specific responsibility for energy efficiency. California was notably the first state to implement comprehensive energy efficiency standards for buildings. At the same time, California's electricity prices remain among the highest in the United States.

Although the importance of saving energy both to ensure system security and alleviate environmental pressures has a long history in California, the 2001 electricity crisis marked a turning point in government and consumers' behaviour on the issue, placing energy efficiency at the top of the political agenda.

Policies and measures

CFL diffusion in California is also influenced by programmes undertaken at the national level, it is therefore important to first briefly recall some of the most important federal level programmes which influence the national CFL market.

Federal level

In 1998, the US Department of Energy (DOE) launched the DOE Sub-CFL Programme to accelerate the introduction of a new generation of smaller, brighter and less expensive CFLs. The programme was based on technology procurement in order to induce manufacturers to develop and sell new CFLs, based on specifications developed in co-operation with the multi-family housing industry. The specific goals were: to induce at least two manufacturers to commercialise new CFLs; to have new CFLs developed that are less than 5 inches long (12.5 cm); to reduce retail prices significantly below the then current \$15–22; and to achieve sales of at least 1 million units. These goals were developed on the basis of market research and the analysis of market barriers. Both the cost and size of CFLs were identified as major constraints to their expanded deployment. Three companies were chosen. The DOE funded technical research, market research, interaction with potential buyers and manufacturers, development of technical specifications, CFL performance testing and promotion. The budget was a modest US\$342,000 and there was no budget for subsidising the CFLs sold. Results were positive. Sixteen new lamp models were introduced onto the market, two 15W CFLs achieved a size less than 5 inches, prices were reduced to between US\$4.95 and US\$8.20, and more than 1.5 million CFLs were sold by August 2000 (Ledbetter, 2001).¹⁴

CFLs were first covered by Energy Star¹⁵ specification in 1999, which has since been revised and tightened several times. Most recent specifications address luminous efficacy, average rated life, lumens maintenance at 1000 hours as well as rapid cycle stress testing and interim lifetime testing. As of February 2006, over 2000 CFL models were qualified under the Energy Star specification (Banwell et al. 2006).

The October 2005 Energy Policy Act plans to introduce minimum energy performance standards for medium screw CFLs.

¹⁴ Source: M. Ledbetter, Technology Deployment Case Study, U.S. Department of Energy's Sub-CFL Program, October 12, 2000 in Creating Markets for Energy Technologies, IEA Secretariat working document

¹⁵ ENERGY STAR is a voluntary labelling programme introduced by the US Environmental Protection Agency in 1999. It is designed to identify and promote the use of energy-efficient products.

State level

Though utilities had launched experimental CFL support programmes earlier on, the first and most important programme was a cooperative effort among California utilities launched in 1999 – the California Residential Lighting and Appliance Programme (CRLAP). The aim of CRLAP was to build market preference for Energy Star-labelled lighting equipment. It included the sponsor of widespread innovative in-store advertising, a state-wide effort to build retailer infrastructure to market products, including professional training of sales representatives, and a product subsidy allocated competitively to manufactures to reduce prices (Calwell et al., 2001).

The 2001 electricity crisis played a decisive role in boosting the California CFL market. In February 2001 the “Flex Your Power” campaign was launched to accelerate California’s conservation activities. It aimed at raising consciousness on the electricity crisis through series of TV, radio, newspaper, and billboard advertising and promotional material. It is estimated that about 25-30% of the 4200 MW of customer load reduction observed in summer 2001 can be attributed to the Flex Your Power campaign (IEA, 2005).

In cooperation with the state government, in 2001 utilities launched widespread CFL programmes to reduce energy consumption, alleviate power outage risks and help mitigate the effect of higher utility bills for low income houses. The programmes were articulated around four approaches to encourage CFL deployment, building on the idea that different population sectors would require different approaches, and thus distinct methods to promote CFLs are needed (Xenergy, 2002; Rasumssen et al. 2003). The four approaches are described below:

- The targeted-event giveaway programs

This program sought to reach specific groups of residents, often by leveraging an existing event or gathering place to reach target audience. Each of California’s utilities offered at least one giveaway in 2001, though with different strategies for targeting various groups, such as senior citizens or low-income households. It is estimated that over 50,000 CFLs were given away through such events (Xenergy, 2002).

- Door-to-door giveaway programs

This strategy, funded by the state government, aimed to give away large amounts of CFLs to targeted groups of residents located in close proximity. The Power-walk was the state’s major door-to-door program and targeted low income households. Through this program the California Conservation Corps distributed over 1.9 million CFLs to 475,000 households (Rasumssen et al. 2003);

- Leveraging of existing programmes

This aimed to maximise the energy saving of existing energy efficiency programs with minor incremental costs. The most important was undertaken by South California Edison (SCE), which increased its energy savings potential by introducing a CFL incentive with its refrigerator-recycling program. It offered participating customers the choice of \$35 or five-pack CFLs. A total of 5,500 people opted for the CFLs, representing 10% of those given the option (Rasmussen et al. 2003);

- Reduced-price programs

Backed by state government legislation, each of the State’s private electric utilities introduced CFL subsidy programs in 2001 financed by government funding and through utility rates. By far the largest scheme was undertaken by Pacific Gas and Electricity, which opted for a \$3 point of purchase rebates. This was sufficiently high in the competitive environment of 2001 to bring CFL prices down to a few dollars. It is estimated that PG&E discounted about 7 million CFLs in 2001 (Calwell et al. 2001).

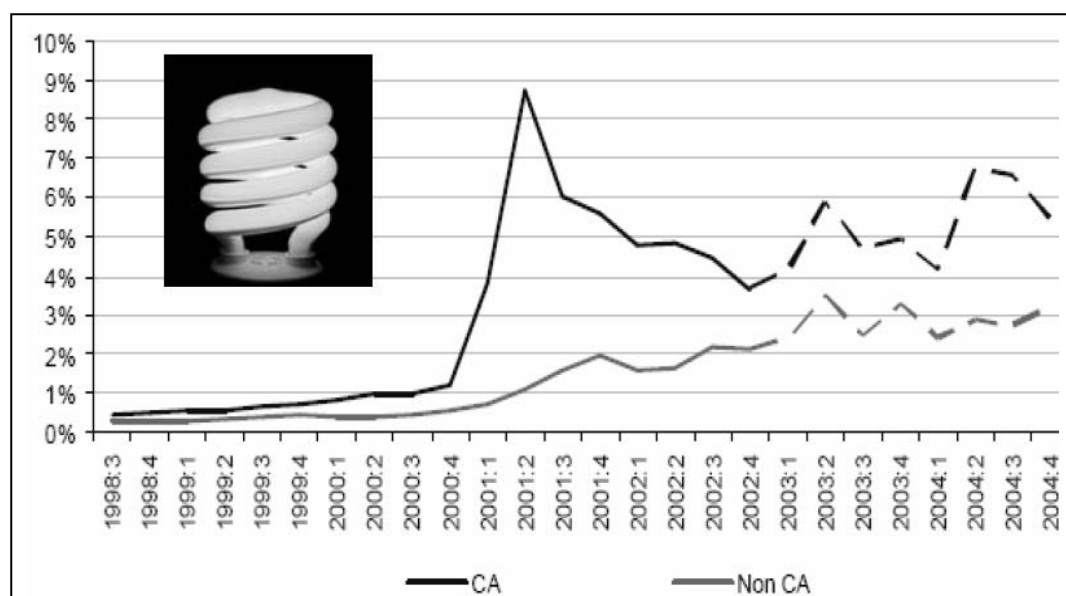
Since 2001 the government has pursued the Flex Your Power campaign in times of tight reserve margins. It is also now encouraging utilities to consider energy efficiency as the preferred alternative to generation.¹⁶ Utilities are also continuing to fund occasional CFL rebate programmes offering usually between \$1 and \$2 per CFL depending on light output.

It should also be noted that California state-wide energy efficiency standards for residential and non-residential buildings were upgraded in 2005 and now include specific requirements for high efficacy lighting notably in permanent lighting or controls.

Impact assessment

As shown in Figure 4, CFL's share of retail screw-based bulbs sales in California grew progressively over the late 1990s to a little over 1% by late of 2000, approximately twice the national level. From the end of 2000 to mid 2001, CFL sales share surged to 8.5% of sales, but subsequently dropped to a little under 4% by end of 2002. Since then CFL sales share has fluctuated with a generally increasing trend reaching 5.5% in late 2004. In contrast, at the country level the share of CFL sales did not see the drastic rise experienced in California. By mid 2001, US sales figure were only at 1% of the market. Since, this share has increased, stabilising around 3% since late 2003.

Figure 4: CFL share of retail screw-based bulb sales in California and USA.



Source: Pfannenstiel (2006)

The multi-mechanism delivery programme of 2001 brought over 10 million CFLs to Californian residents. Each delivery mechanism was selected so that the program could meet a specific set of objectives, such as reaching a targeted audience or achieving maximum energy savings. Targeted event giveaway used existing local events to cost-effectively reach out specific groups of residents. The Power-walk program effectively reached half-a million households building on existing networks through California Conservation Corps. Offering a portfolio of programs that relied on multiple delivery mechanism seems to have been an effective strategy both in terms of output and costs.

¹⁶ This is notably included in California's Energy Action plan: http://www.energy.ca.gov/energy_action_plan/index.html

A survey of California's lighting program (Xenergy, 2002) reveals that awareness of energy efficiency in general and of energy efficiency products and technologies has increased over time. The survey indicates that about 75% of the 2001 programme participants were already aware of CFLs' use and existence prior to the programmes. Except in the case of Power-walk participants where less than half had prior knowledge of CFLs. It is therefore unclear how effective the awareness raising components of the 2001 programmes were.

Although these results are very promising, the programme's context and timing was preponderant in making its success. As seen, many external factors contributed to consumers' awareness of energy efficiency, most notably California's energy crisis in 2001. Moreover, the same report also reveals that, the most important quoted explanation amongst the "CFL aware participants" for not using CFL, was "too expensive" (39%). While utilities continue to implement occasional CFL subsidy programmes, greater and sustained emphasis on the first cost barrier may be an effective means to achieve greater CFL penetration.

4.3 China

Context

Rapid economic growth over the past two decades in China has led to significant increases in electricity demand, averaging at 8% per year over the 1990s and at 13% between 2000 and 2004.¹⁷ With a growth rate of approximately 15% over much of the 1990s, lighting has been one of the fastest growing electric end-uses.

The rapid growth in domestic electricity consumption has had important environmental and supply security implications. The burning of fossil fuel in power generation plants, and in particular coal, has contributed to the significant rise in air pollution as well as of CO₂ and other greenhouse gas emissions. Generation capacity additions have also, at times, failed to keep up with demand growth making black-outs and brown-outs common occurrences in many provinces.

In the same time China has seen a dramatic rise in its production of energy efficient lighting products including CFLs. Between 1997 and 2003 Chinese CFL production increased from a little under 200 million units to over one billion (Chen, 2005) leading to significant production cost reductions. China has notably become the leading exporter of CFLs to OECD countries and in particular the USA. Yet the intense competition between CFL manufacturers and the lack of any regulatory guidance over most of the 1990s has led to inferior quality products getting to markets and growing consumer distrust.

Policies and measures

The combined environmental and electricity supply security concerns has made energy efficiency an increasingly important aspect of China's energy policy. It was notably highlighted as one of the 15 priorities of the 10th Five-Year Plan (2001-2005). This, in parallel to the potential economic benefits of a sustainable energy efficient lighting industry, has brought the government, in cooperation with UNEP and the GEF, to define a wide-ranging policy package in which CFLs plays a predominant role. The project is officially called "Barrier removal for Efficient Lighting Products and Systems in China" but more commonly referred to as the China Green Lights Project.

The Green Lights program was originally initiated by the Chinese government in 1996, yet its successor (2001-2005), in which UNEP and the GEF have an active role as supervisors and funding partners, is significantly more far reaching and ambitious. The project has as its main objective to "*reduce lighting energy use in China in 2010 by 10% relative to a constant efficiency scenario*" and as a secondary goal "*to increase exports of efficient quality lighting products, aiding the Chinese economy and helping to reduce energy use and GHG emissions worldwide*" (UNDP, 2000).

¹⁷ Source: IEA data.

The project includes the following policies and measures articulated around three axes:

- Increase the supply of high-quality lighting products

On 1 August 2003, minimum performance standards that all CFLs must achieve to go on sale were adopted to progressively remove the worst performing products from the market. In addition, a more stringent, optional certification standard was created (Table 4). A third standard, the REACH standard was created to give advance notice to manufacturers as to the evolution of the minimum performance standard.

Table 4: Energy efficiency threshold for CFLs in China¹⁸

Range of rated wattage (W)	Initial Luminous Efficacy (lm/W)			
	Energy efficiency grades (Colour temperature: RR, RZ)		Energy efficiency grades (Colour temperature: RL, RB, RN, RD) ^{a)}	
	Certification	Minimum	Certification	Minimum
5~8	46	36	50	40
9~14	54	44	58	48
15~24	61	51	65	55
25~60	67	57	70	60

In order to support the implementation of these standards, measures were introduced to improve the consistency between lighting equipment test laboratories.

Buildings standards for new buildings have also been implemented. By the end of 2004, mandatory Energy Standards for Lighting of Buildings were devised for 6 building types (office, commercial, and industrial buildings, as well as hotels, hospitals, and schools) and a voluntary standard was approved for residential buildings. In each case minimum luminance levels necessary in different areas of each building type and the maximum allowable power to supply that lighting level were set.

Another measure has been to survey the supply chain of the raw materials used in the manufacture of efficient lighting products to identify opportunities to improve the quality and efficiency of end products.

- Create demand for energy efficient lighting products by raising awareness and understanding among key categories of consumers

One measure devised to raise the awareness of consumers has been to create an endorsement label for products which meet the certification standard. The idea is that through this label, consumers would more easily recognise the high quality lighting products. Quality counters have also been setup in a number of department stores to promote energy efficient lighting products separately from conventional lighting products and to provide an area for defect products to be returned.

Another component here has been mass media promotion of energy efficient lighting technologies through print media (articles in news papers and magazines) and dedicated television programs. Specialised documentation and training programs have also been produced to raise the awareness of professionals.

- Creating sustainable financing options to make efficient lighting affordable

A cooperative bulk purchase programme has been set-up to organise purchasing groups and organise tenders in order to lower purchase prices and create sufficient demand for certified energy efficient products. This

¹⁸ Source: www.cn-greenlights.gov.cn/english/e-index.htm

has been linked to a subsidy program for products purchased through bulk purchasing (1\$ per CFL). Similarly, a DSM program for utilities has also been created, also linked to a subsidy program (0.5\$ per CFL) to purchase certified lighting products.

Impact assessment

Assessing the impact of the Green Lights project is not a straight forward task due to the difficulty in separating project impact from the rapid evolution of the Chinese CFL market that would have occurred anyway. In addition, most project activities may not have immediate impacts but more progressive implications on the lighting market beyond the timeframe of the program, which has only lasted until 2005. Nevertheless, numerous evaluations of the Green Lights project (e.g. Du Pont, 2005; UNDP, 2003) have been undertaken and experts who have worked on the China Green Lights project or who are familiar with the Chinese lighting market can be a useful source of information.

The CFL (and other energy efficient light products) certification scheme seems to be one of the most successful elements in support of enhancing the diffusion of high quality CFLs. Through the bulk purchasing and DSM subsidy programs a total of approximately 3.8 million certified CFLs have been purchased creating an initial demand for certified products. In addition a new policy enacted by the Chinese government in December 2004 requires the preferential purchase of labelled energy efficient models of products subject to mandatory procurement. The program started in 2005 and by the end of 2006 will be rolled out to all levels of government, including central, provincial, and local governments.¹⁹ Self-ballasted fluorescent general service lighting equipment is included in the first list of certified products that government should purchase further creating strong demand for high quality CFLs.

The certification scheme, managed by the China Standard Certification Centre, is in a financially sound situation as manufacturers must pay the cost of certification, which includes mandatory product testing. Over time the stringency of the certification standard is expected to increase. Yet while the political and economic rationale for this is evident this has not yet taken shape.

The certification scheme also benefits from the successful harmonisation of lighting product test procedures in the main testing laboratories of Shanghai and Beijing, which are used to certify CFLs. In addition, this process has led China to cooperate with US test laboratories, through round-robin comparison tests. This has notably led the test laboratories to take part in the international Energy Efficiency Lighting (ELI) project gaining further recognition as rigorous and reliable test centres. On the medium term, the establishment of internationally recognised test laboratories is expected to further facilitate the export of high quality CFLs to countries with domestic quality standards in place. It should be noted that China is also part of the International CFL harmonisation Initiative.

Another potentially important measure is the creation of lighting standards in buildings including a voluntary standard in the residential sector. Considering the pace of building construction in China – in 2003 there were about 14.1 billion square meters of new construction of which 63% were for residential use – this could have a significant impact on lighting demand. Building professionals are being trained and a standard enforcement scheme has been established.

Even though they are not stringent, the minimum energy performance standards are not likely to be particularly effective in removing the worst performing CFLs from the market. It is estimated that there are approximately 1000 Chinese manufacturers of CFL, with many in remote provinces, so ensuring standards are respected is an extensive task. However, the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), which should be in charge of the enforcement of the standard, does not seem to have the capacity to ensure the standards are respected. In addition while the two main test laboratories in China are effective, many provincial and local testing centres do not have the competencies to effectively test

¹⁹ Schools and hospitals are included in such government procurement policies.

for lighting products. Training of staff is underway yet this is likely to be a long process as well as require the purchase of specific testing equipment.

The awareness building component of the Green Light project has not been successful. The main criticism being that the magnitude of the task, considering the size and geographic distribution of the Chinese population, was underestimated and that without the cooperation of manufacturers, effective awareness building is a considerable task.

4.4 South Africa

Context

South Africa's final electricity consumption has grown by over 50% since 1990.²⁰ Eskom, the state-owned national utility, generates 95% of the total. Growing electrification of the residential sector - from 36% in 1994 to 71% at the end of 2004 (Eskom, 2005) - has resulted in "peakier" electricity demand, thereby putting increasing pressure on the energy system. This has made security of energy supply and the threat of blackouts serious concerns for the government (Anton, 2004).

The 1998 Government White Paper for Energy set forth these issues and suggested different tools and reforms. These include the application of efficiency standards, appliance labelling, mandatory energy audits, and certification systems. The White Paper also underlined the need to restructure the electricity market and considers the privatisation of 30% of the generation stage, as well as unbundling generation and transmission. None of these measures have so far been implemented and therefore no private capital has been injected to support growing investment needs.

Policies and measures

South Africa was one of seven countries to take part in the World Bank/GEF Efficient Lighting Initiative (ELI). Bonesa - the name of the company set up to operate ELI in South Africa - ran from 1999 to 2002. Bonesa focused on 50,000 houses and aimed at replacing all lamps by CFLs. One of its primary objectives was to reduce the price of CFLs. Price information shows that it succeeded: CFL prices went from R60/80 per lamp in 1998, to R13/20 in 2004 (Eskom, 2005).²¹ By training staff from the local communities, Bonesa also contributed to enhance local expertise in CFL technologies and advantages.

At the end of the three year period, Eskom implemented a residential DSM programme. It had a two-fold objective: (i) to reduce electricity demand at peak periods by shifting load to off-peak hours; and (ii) by reducing overall electricity demand through the implementation of energy efficiency measures.

The national efficient lighting roll-out initiative, part of the DSM programme, was launched by Eskom in 2002 to provide lower cost alternatives by focusing on the effective usage of electricity. Between 2003 and 2005 about 2,5 million CFLs were distributed through subsidised prices (Donet, 2006).

Similar initiatives were later reproduced through regional programmes such as the latest Western Cape initiative launched in April 2006. This allowed the replacement of over 4.3 Million CFLs within three months (Eskom, 2006), mainly through door to door give away campaigns resulting in a 193MW saving, exceeding the 155 MW target.

The DSM programme also launched awareness campaigns which sought to familiarise consumers to CFLs' environmental and financial benefits. Power alert campaigns were also launched to limit peak demand:

²⁰ Source: IEA data

²¹ From about 6,40 /8,70 € to 1,40/2,20 €

consumers are encouraged to stay tuned to their radio stations and televisions wherein suppliers communicate the level of shedding. With a four colour code ranging from green to brown, Eskom intends to alert consumers of the implications in their use of electricity and appliances in the household.

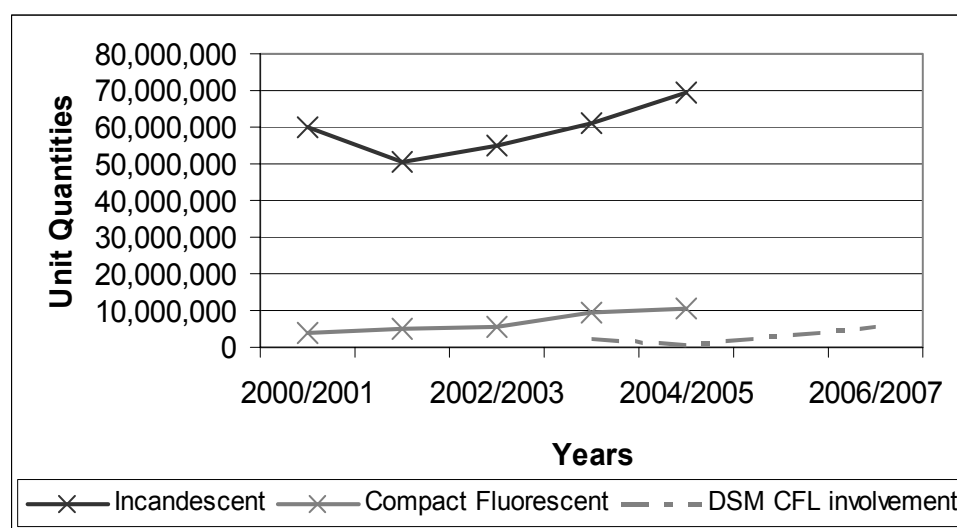
Impact assessment

By the end of the ELI programme, CFL sales had increased by 64%, while the sales of incandescent lamps decreased by 9% (GEF, 2004). The initiative contributed to lower CFL prices, raise awareness and enhance awareness of CFL benefits.

Since the implementation of the residential DSM programme in 2002, 10.6 million CFLs have been distributed (Donet, 2006). Among those, 5 million were distributed through a free exchange programme whereby customers got CFLs free of charge in exchange of their incandescent bulbs.

Furthermore, national sales figures show that CFL sales have increased significantly since 2000 (figure 5). In 2000/2001 the sales were of approximately 4 million units while in 2004/2005 they were of about 10,5 million – a growth of over 260% in about six years.

Figure 5: Evolution of CFL and incandescent lamp sales in South Africa



Source: Eskom, 2006

Figure 5 also shows, however, that sales of incandescent lamps have increased over the same time, at a faster rate than CFL sales. Today CFL sales represent 8% of the total sales of lighting products in the residential market (Donet, 2006).

The combined ELI and DSM programmes have addressed several barriers to CFLs deployment. The initial cost barrier for example has been addressed through the market transformation program which resulted in a decrease of 60% of CFL prices in the South African market as well as through the various subsidy and give away programmes. The DSM programme addressed information and awareness barriers through wide spread information campaigns as well as the training of sales personnel.

4.5 United Kingdom

Context

The UK was the first country to deregulate its electricity market. The legal framework enabling the effective launch of liberalisation took shape in 1989 with the Electricity Act. A series of reforms then followed which culminated with the Utilities Bill in 2000. Today there are 17 electricity distributors, 7 of which national; all of which free to set their prices and organise their development as they want. Since competition was introduced in 1990, real electricity bills for individual consumers have declined by 30% on average (IEA 2002). However, UK's household electricity prices remain higher than in other countries where prices are regulated (e.g. France).

The UK is active in trying to reduce greenhouse gas emissions. It signed the Kyoto Protocol in 2002 with other members of the European Community (EC). Under the EC burden sharing agreement, the UK has a target of reducing greenhouse gas emissions by 12.5% below 1990 levels in the first commitment period (2008-2012). More recently the government adopted an ambitious goal of reducing greenhouse gas emissions by 60% by 2050.²²

The UK has already surpassed its Kyoto target having reduced emissions by 14% between 1990 and 2004 alone. Energy Efficiency is at the heart of the UK strategy to reduce emissions. Improved energy efficiency is estimated to represent 35% of the emissions reductions achieved so far, the single most important factor identified (Defra, 2006).

Policies and measures

As part of the European Union, the UK is obliged to implement measures contained in EC Directives. Two directives have particularly far reaching implications for CFLs and should be mentioned here. The first is the 1998 EU Directive²³ which made energy labelling of household lamps mandatory. It requires all lamps sold to the domestic lighting market to carry an energy label that is similar to the A to G energy label used for household appliances. It is unique because it is the only international policy instrument that applies a common grading scale across different lamp types i.e. all household lamps, regardless of type, are assessed and graded using the same energy efficiency metric. In other countries lamp labelling is only done within product classes i.e. CFLs may have one efficiency rating system and incandescent lamps another. Under the EU scheme CFLs are typically rated as class A or B, halogen lamps as class C or D and incandescent lamps E, F or G.

The second directive of importance is the directive on energy efficiency requirements for ballasts in fluorescent lighting²⁴ which imposes minimum energy performance standards for ballasts. Through this directive sale of the least efficient ballasts will be phased out in the EU area. Class C ballasts have notably been phased out in the EU since the second phase of the Directive came into force on November 21st, 2005. This should have strong impact since over 50% of CFLs sold in recent years used class C ballasts.

In addition to the EU label, UK has implemented a CFL-performance certification scheme to ensure the quality of CFLs available on the market, and mitigate the risks of unsatisfied customers. The scheme is operated by the Energy Savings Trust (EST) who maintains a list of recommended CFLs that are eligible to carry an "energy efficiency recommended" logo. These must meet stringent performance standards for

²² 2003 Energy White Paper

²³ Directive 98/11/EC

²⁴ Directive 2000/55/EC

efficacy, colour rendering, lumen maintenance power factor and warm up time. Over a hundred CFLs on the UK market currently meet the requirements.

Several broad policies have important implications for CFL diffusion in the UK. The UK Energy Saving Trust, set-up in 1994, has operated a number of programmes for energy efficient lighting which have been sponsored by either the regional electricity companies or generating utilities. From 1994 to 2002 the Standards of Performance programmes (SOP1-2-3) were operated. They were followed by the Energy Efficiency Commitment (EEC). In April 2002, the Government launched Phase 1 of the EEC, which lasted until March 2005. The EEC's goal was established as (i) support the Government in reducing carbon emissions and (ii) help to reduce fuel poverty by ensuring half the energy savings are targeted at households in receipt of certain income-related benefits or tax credits (Energy Saving Trust, 2004).

The EEC is an obligation on gas and electricity suppliers to meet energy saving targets by promoting energy efficiency improvement measures in the household sector. The Department of Environment, Food and Rural Affairs ("Defra"), sets the targets while the national gas and electricity regulator Ofgem monitors the process. The target for the first phase, set at 62 TWh, was surpassed. The new targets for phase 2, which runs from April 2005 to March 2008, is 130 TWh. With regards to CFLs, only models which meet the EST performance certification scheme specifications are eligible for inclusion in the UK Energy Efficiency Commitment.

The UK 2002 L1 regulations applying to domestic buildings required that, depending on the number of rooms created, new homes to be fitted with a number of internal, fixed light fixtures and one external, fixed fixture with an efficacy of >40 lm/W, a level above conventional incandescent lamps and halogen lamps efficacy levels but ideal for fluorescent lamps such as CFLs. The 2006 regulations specify that compliance with codes can be attained by installing at least one fixed luminary that only takes one efficient lamp (>40 lm/W efficacy) per 25 m² of floor space as well as one such fixture per four fixed fittings. These provisions also apply to lighting in building refurbishments. Moreover, the overall residential building energy performance standard is based on a target CO₂ emissions rate for heating, hot water and lighting, but the overall stringency of the minimum energy performance requirement has increased by 25% compared with the 2002 code and thus will provide an additional incentive to use efficient lighting fixtures in new homes (ODPM, 2005).

In addition the EST and the UK Lighting Association have begun to operate a Domestic Energy Efficient Lighting Scheme ("DEELS") to address the traditional low efficacy of domestic luminaries (i.e. table lamps, standing lamps, or other portable luminaries aimed at the domestic market). The scheme gives a GBP5.0 subsidy supplied through EEC2 to luminary manufacturers that produce and sell CFL dedicated luminaries i.e. ones which can only take pin-based CFLs with separate ballasts. The luminaries have to use high efficiency 50kWhz ballasts with a minimum life of 25000 hours and the CFLs are certified through the EST certification scheme. By using pin-based CFLs there can be no switching back to incandescent light sources once the first CFL tube fails. The first year target is to sell a million luminaries of which 400 thousand were sold in the first seven months. The Lighting association subsidises the ballast and the lamp up to £4.90 (Verdun 2006).

The Lighting Association has also put in place an Energy Efficient Lamp Scheme ("EELS") which subsidises lamps to offer a better price to independent lighting stores, to increase CFL distribution. As such the Association acts like one large account which handles the payment and orders so that the major lamp makers don't have to deal with small accounts. It offers subsidised CFLs to the retailer for as low as 25 pence + VAT each (Verdun, 2006).

More recently, the UK was amongst the first countries to participate in the international CFL harmonisation initiative launched in the end of 2005. The ultimate goal of this initiative is to deliver higher-quality, low-cost CFL lighting products to consumer worldwide. The initiative focuses on four core areas:

- Performance specifications;
- Creating a uniform testing method, covering the performance features of self-ballasted CFLs, suitable for submission to national and international standard bodies to measure CFL performance;
- Identifying a number of performance specifications for self ballasted CFLs to facilitate testing comparisons and possible rationalisation of CFL performance requirements; and
- Proposing these initiatives to the wider international lighting community.

The endorsement of this International CFL Harmonisation Initiative does not imply any specific obligations or requirements. So far five governments other than the initiator Australia have endorsed the initiative: the UK, US, Philippines, China, and New Zealand. Although it is too early to evaluate its impacts, clear proposals on common testing and performance specifications have already been developed.

Impact assessment

The July 2004 EEC mid-term report published by Defra states that by the end of the EEC's second year, the suppliers had fulfilled over three quarters of the overall commitment of 62TWh. The report also shows that provisions of free, or subsidised CFLs to customers, has been the most common tool used by suppliers to meet their EEC obligation (Defra 2004). However, the EEC does not place much emphasis on directly influencing consumers' behaviour. One could imagine that a new campaign would focus on emphasising benefits that CFLs have on their bills rather than merely impose them.

The results of the programmes have become progressively more significant such that for the EEC1 programme some 39.5 million high quality certified CFLs were supplied in the three years from 2002-2004 to the residential market. This is three times the baseline scenario of 12.5 m lamps and is believed to have doubled UK CFL ownership to over two per household. About 25% of the total energy savings of 64 TWh from EEC1 are estimated to derive from CFLs (IEA, 2006).

Mandatory energy labelling of light bulbs have influenced consumers' behaviours and is directly felt on the evolution of CFL's sales (Fawcett, 2001). The lack of Information and standards had long been emphasised as barriers to more CFL deployment.

Since the beginning of EELS and DEELS, more than 500,000 luminaries have been subsidised by the lighting association (Verdun 2006). Furthermore, over 230 independent retailers are now involved in the CFL distribution process. They have in the last 17 months sold over 200,000 CFLs (Verdun 2006).

5. Discussion and Conclusion

Substituting incandescent lamps with CFLs yields economic benefits and reduces energy consumption thereby contributing to climate change mitigation and to ensuring the security of the energy system.

A number of countries have policy programmes in place to overcome some of the barriers to CFL diffusion. The five case studies considered are set in very different contexts. In the case of Brazil and California, the power crises of 2001 were the main drivers which led to the implementation of the CFL diffusion programmes. In the case of China, while environmental and energy security were important, the prospect of a sustainable global energy efficient product industry most probably played a determining role in the government's efforts to enhance CFL diffusion. In the case of South Africa, CFL programmes are utility driven and have been defined in response to power supply security and financial concerns. Finally, in the UK, reducing greenhouse gas emissions seems to have been the main driver of CFL and other energy efficiency measures.

The policy context in which CFL diffusion programmes are implemented is important as it influences the types of measures adopted and determines the level of support within and outside of government. Governments should therefore not focus on one of the attributes of CFLs diffusion but rather emphasise the multiple benefits – in terms of security, climate and economics – of CFL programmes to broaden and deepen their political foundation.

While the barriers to CFL diffusion discussed in section 3 exist in all the cases considered there are significant variations in their magnitude depending on the country and its socioeconomic conditions. CFL penetration in advanced developing countries such as Brazil and China is notably much higher than in most – if not all – OECD countries. While the policy programmes discussed have contributed to this success, this reflects more profound differences between OECD and less developed countries.

With regards to the first cost barrier, for example, the problem is almost inexistent for high income consumers while it can be very important for low income consumers. The high penetration rates in rapidly developing countries such as Brazil and China may reflect an intermediate case where income is high enough to afford the high first cost of CFLs yet not so much as to not give importance to electricity bills. A greater emphasis may therefore be placed on life cycle costs and the need to optimise investments in energy efficient technologies. In contrast, in OECD countries the comparatively limited weight of electricity bills on disposable income may imply that households give less importance to energy efficiency considerations and therefore emphasise lower first cost equipment.

Similarly, incandescent lamps have been the reference technology in the residential lighting sector in most OECD countries for decades. In comparison, households in less developed countries such as Brazil, China or South Africa, where electrification has been much slower and where the number of lamps in homes is more limited, have had much less experience with incandescent lamps. As a result there may be less technological path-dependence around incandescent lamps and societies in developing countries may therefore be more inclined to switch to CFLs than in OECD countries. The technological inertia seems therefore more limited in less developed countries.

There are also important differences among OECD countries. Linear fluorescent lamps already play a significant role in Japan and many other Asian countries. There may therefore be more limited behavioural resistance to the substitution of incandescent lamps with CFLs, as these share many technological properties with linear fluorescent lamps, compared to countries where incandescent lamps are the dominant technology.

It is therefore important for a country wanting to set up a policy programme to enhance CFL penetration to clearly identify the barriers specific to their country's socio-economic circumstances in order to optimise and target policy choices.

From the case studies considered a number of policy lessons can be drawn. First, lowering the price differential of CFLs compared to incandescent lamps, by direct subsidy, soft-financing, or through give away programmes is effective in supporting market growth. It also provides a strong foundation to demonstrate long-term CFL cost benefits. As seen in California and South Africa, in addition to quickly lowering electricity demand, a well designed scheme can also lead to clear and rapid benefits for utilities in terms of avoided investments and reduced financial risks. Increasing the penetration will also help further diffusion by stimulating 'word-of-mouth' marketing – important to reach previously disaffected consumers.

Second, proactive promotional campaigns can be effective, though as seen in the Chinese case these are often costly and difficult to organise and manage. One of the criticisms of the Chinese efforts is that manufacturers and utilities were not sufficiently active. While not a desirable condition, awareness campaigns seem to have been particularly effective when there is pressure on the energy system, such as a power crisis, as this forces all market participants to take part in raising awareness. In any event, awareness campaigns should be organised in collaboration with utilities, manufacturers and consumer groups.

Third, ensuring the quality of CFLs can be effective in building trust in the new product. As seen in the case of China in the 1990s, intense competition and limited regulatory oversight have led the domestic market to be dominated by inferior products with the risk of giving the technology a poor reputation and preventing

good CFLs from attaining the market share they otherwise would. Consumers may not take the risk of purchasing a relatively expensive lamp if they think it might flicker, fail long before its claimed life-span, produce significantly dimmer light, have a poor colour-rendering or take a long time to warm up. There is therefore an incentive to ensure the quality of products in the market. It should however be noted that by doing so you also remove the cheapest products on the market and may therefore create or consolidate the initial cost barrier mentioned above. Policy makers should therefore appreciate the correlation between product quality, consumer perception and price.

Through its bulk procurement and DSM programmes, China has offered strong incentives for certified quality CFLs. The new requirement that all government purchases be certified quality products should further broaden the market of quality controlled products. Similarly, the UK's Energy Efficiency Commitment has created a strong market for certified quality products. While successful these schemes highlight the high level of cooperation needed between government, industry and test centres to create a market for high quality products. The Brazilian experience of certification standards not being raised as the market developed leading to certified products flooding the lighting market reflects how such a scheme can lose credibility if not carefully monitored.

Also, it seems that some of the successes obtained in the programmes considered were at least in part due to the fact that they addressed multiple barriers. In the case of California and Brazil for example, much of the success of the subsidy and give away programmes (first cost barrier) can be attributed to parallel efforts to raise public awareness about energy efficient product benefits and in particular energy saving, economic and life-span advantages of CFLs (information/behaviour barrier). The UK measures address the information/awareness barrier through the EU and UK labelling schemes, the first cost barrier through the energy efficiency commitment, as well as the technological barrier through the innovative collaboration with residential sector luminary manufacturers.

Finally, programmes need to be sustained long enough to provide consistent messages. The CFL programmes mentioned here are only the first phase in a broader strategy which, as in the UK, should include measures to develop a market for pin-based luminaries. Otherwise, there is always the danger that consumers will switch back to incandescent lamps at some stage in the future.

Policy-makers must therefore always think of why market actors might not engage in their programmes as well as why they should plan strategies to reduce resistance and inertia as well as to provide positive incentives to engagement. Effective policy development considers all the perspectives and factors influencing market engagement and designs instruments to address the key barriers until a positive tipping point is passed. It is best if this can be done from the outset. However, it is usually not possible to foresee all factors in advance, so policy implementation should build in a monitoring and evaluation feedback process to: (a) document and evaluate impacts, and (b) analyse the effectiveness of implementation so that unexpected difficulties can be fixed through ongoing refinement. This seems obvious, though as seen in the cases considered, not all programmes have monitoring and evaluation processes in place.

In sum, promoting the diffusion of CFLs as a government policy presents unique benefits in terms of climate change mitigation and enhanced energy security. The technology is continuously evolving and is now sufficiently mature to replace most types of incandescent lamps. Policy tools exist to effectively accelerate the penetration of CFLs.

Governments may also consider more ambitious approaches. The complete phase out of incandescent lamps may notably constitute an ambitious though achievable policy objective. Governments may therefore consider collaborating to define an international agreement to phase out incandescent lamps. Governments may also wish to use the case of CFLs to push for more CDM projects targeting energy efficiency.

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ANNEX

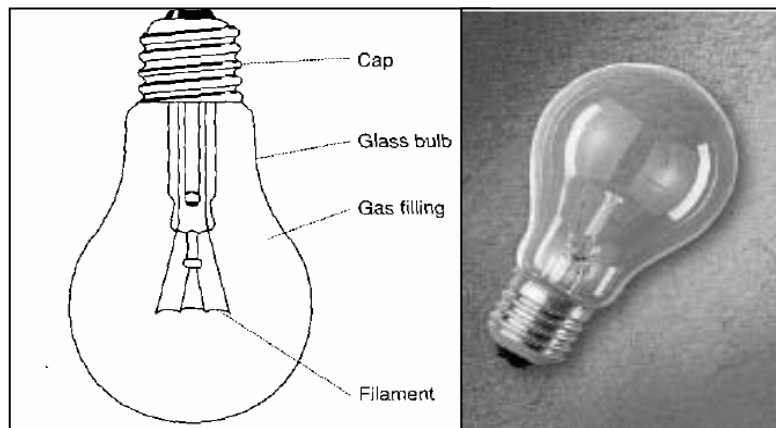
Conventional incandescent and compact fluorescent lamps: basic characteristics

Incandescent light bulbs

Incandescent lamps consist of a bulb containing a wire filament that is heated and emits light. Up to 95% of the energy emitted by incandescent lamps is in the invisible infrared (heat) end of the light spectrum and hence the efficiency of incandescent lamps is inherently low. Incandescent bulbs may have different types of bulb finishes to modify the brightness of the filament, internal reflecting substances on the bulb to control the direction of the light, halogen gases, and special tungsten filaments. Tungsten is used because it has a relatively high melting point and a relatively low rate of evaporation at high temperatures. The filament is surrounded by a gas (argon in standard incandescent lamps) to reduce the tungsten evaporation rate and this raises the temperature the filament can operate at and hence the light output. However, the gas also conducts heat away from the element, which lowers the overall efficacy.

The first practical incandescent lamp was developed in 1878 and design improvements continued to be made up to 1936 at which time efficacy levels have increased by approximately a factor of 10. No further developments occurred until the halogen lamp, which is also based on the process of incandescence to produce light, was developed in 1958. The most common type of argon-filled incandescent lamp is known as a general service lamp (Figure 6).

Figure 6: Common incandescent general service lamp



The number of starts does not affect the life of the bulb, but at an average of just 1,000 hours their lifetime is significantly shorter than other alternatives. Incandescent lamps create comfortable colour lighting, are easy to dim, operate over a wide range of temperatures and, above all, are cheap to purchase and readily available in many types of retail outlets. Their chromaticity characteristics give near perfect colour rendering but they are only able to produce warmer light. The most common incandescent lamps distribute light diffusely in all directions from a near pear shaped bulb; however, they can be housed inside reflectors to provide narrower or shaped light distribution when required. Incandescent lamps are also commonly available in a large variety of decorative forms such as candle and flame shapes.

Their low price, warm colour and longstanding familiarity have led incandescent lamps to be the most commonly purchased lamp globally and they are particularly prevalent in residential lighting applications in most countries. However, they suffer from very poor efficacy, which leads to disproportionately high energy and overall lighting service costs. Although the efficiencies of incandescent lamps have been improved since their first development, they still have the lowest lighting output efficacies of any modern electric lamp type: ranging from 6-18 lumens per watt.

Compact fluorescent lamps

CFLs (Figure 3) were first commercialised in early 1980s and are offered in two types: with the ballast integrated into the lamp, or without the ballast integrated. The former are intended as direct substitutes for incandescent lamps and are designed to fit into existing incandescent lamp fixtures, while the latter are orientated more at commercial building retrofits and new-build as alternatives to incandescent lighting installations. CFLs usually consist of 2, 4 or 6 small fluorescent tubes that are mounted in a base attached to a ballast for ballast-integrated models, or are plug-in tubes for the non-integrated variety. Integrated lamps use either a screw-in base or bayonet cap in the same way as standard incandescent lamps. More recent models are available in a variety of screw-in diameters and so will fit into a much larger range of lamp sockets than earlier generations. The light output of integrated CFLs are designed to match those of equivalent incandescent lamps, but as their efficacies are from 4 to 5 times higher the wattage ratings are proportionately lower. CFL efficacy ranges from 35 to 80 lm/W.

CFLs consume a 1/4th to 1/5th of the energy used by incandescent light bulbs to provide the same level of light. About 25% of energy consumed by CFLs is converted to visible light as compared with just 5% for a GLS incandescent lamp. This relatively high efficiency means many CFLs are cool enough to touch while operating and hence are safer. Another important benefit is that they have much longer lifetimes compared to incandescent lamps with rated life spans of 5000 to 25000 hours.

Figure 7: Compact fluorescent lamps – ballast integrated models.

