Compact fluorescent lamps in an international context

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1. Introduction

This paper is the first of a series of papers to be produced by the Energy and Development Research Centre (EDRC) on energy-efficient lighting. The research falls under EDRC's Energy Efficiency, Equity and the Environment project which is co-sponsored by Eskom and the International Development Research Centre.

This document reviews particular aspects of some of the well documented energy-efficient lighting programmes instituted in different parts of the world. To improve residential lighting efficiency, most programmes have relied upon promoting compact fluorescent lamps (CFLs). This paper deals specifically with the adoption of this technology. It reviews experience from CFL programmes undertaken in Mexico, Brazil, India, Europe (in general – though particularly Sweden, Austria, Denmark, Ireland and Poland), Thailand, China, Pakistan, the Caribbean, and the United States. Attention is also given, but not confined to,[1] programmes targeting low income households. The review draws from literature documenting aspects of particular programmes, but also from extensive communications with project staff closely involved in planned, completed and ongoing projects.[2]

2. Global trends, demand-side management initiatives and residential lighting

World electricity generation grew from 5 PWh in 1970 to 12 PWh in 1991 (Levine et al 1992). This can be attributed predominantly to high rates of population growth around the world and, in particular, to the rapidly expanding developing countries' desire to attain similar standards to those of developed countries. By 1993, about 60 GW of new capacity was being added every year (Flavin & Lennsen 1994). Developing countries' share in this capacity grew from 11 per cent in 1970 to 16 per cent in 1980 and 22 per cent in 1990 (Levine et al). The average growth rate of electricity use in developing countries from 1980 to 1990, was 6.9 per cent. This growth represented more than double that of OECD countries; furthermore, if growth in the future in any way resembles growth of the 1990s, developing countries' demand could potentially amount to about half of the world's total of around 40 PWh in 2020, and 50 GW of new capacity will be required to meet the demand in developing countries alone (Meyers & Campbell 1992). It is unclear how the projected expansions in electricity demand will be coped with, from financial, institutional or environmental points of view.

In response to the obvious constraints on this continued rapid expansion of electricity demand in both developed and developing countries, and then sparked by the energy crisis of 1973 and 1979, OECD countries began in the early 1980s to investigate the potential for utilising not only supply-side but also demand-side measures to evaluate the requirements that would potentially be placed on the power sector of the future. This method – referred to as integrated resource planning (IRP) – encompasses demand-side management (DSM) activities or support given by electricity utilities for the development and introduction of an array of energy conservation measures (Pye 1992).[3] DSM requires that utilities focus on providing energy *services* rather than on being mere sellers of electricity. Many of these DSM programmes promote the use of more efficient lighting, refrigeration, and air-conditioning technologies. Importantly and interestingly, the experience and success of DSM in developed countries has served as a backdrop to

1 This stance is taken because lessons learnt by programmes to middle- and upper-income households are clearly valuable in their particular contexts to programmes directed towards low income households.

2 This paper's bias is that most of the literature reviewed and communications undertaken emanate from Lawrence Berkeley National Laboratories (LBNL), International Association of Energy Efficient Lighting (IAEEL), and the International Institute for Energy Conservation (IIEC) .

3 Often DSM approaches rely on the introduction of more electricity-efficient technology.

the growing efforts in developing countries to examine the potential for saving electricity (Friedmann 1996).

Coupled with this new attention to DSM in developed and developing countries is the growing interest paid to the residential or household sector. Perhaps most importantly, households are the main contributors – despite recession – to peak electricity demand (household electricity demand fluctuates more than industrial and commercial usage). Although not the largest user of electrical energy in any particular economy, the residential sector has the most dynamic potential of all sectors for growth in demand. This is particularly true of households in developing countries where increased levels of urbanisation, and thus the provision of electricity, and the absorption of household appliances facilitate such demand growth. It has been suggested that the potential for the largest savings in electricity can be derived from households in developing countries, because they are generally not using the most efficient appliances available, and significant savings can thus potentially be achieved with the adoption of newer technologies.

Residential energy efficiency lighting programmes present utilities with promising potential for reducing demand. The reasons for this are:

- lighting consumes 8-17 per cent of total electricity produced in industrialised countries and the share in developing countries can be larger;
- energy use can be reduced by as much as 75 per cent without reducing lighting levels – such a reduction is difficult to achieve in most other end-uses;
- lighting is often the first end-use of electricity in the residential sector;
- some uses of lighting coincide with peak electricity demand and, therefore, a reduction in energy use can alleviate the growing peak load;
- lamps have a relatively short life compared to other capital equipment and, therefore, savings can be quickly realised through an implementation programme which capitalises on this high turnover rate (Dutt nd; Nadel 1991).[4]

3. Energy-saving CFLs

All fluorescent lamps operate by discharging an electric arc through a mercury plasma enclosed in a glass envelope. The (mostly) ultraviolet photons emitted by the de-excitation of mercury atoms are converted to visible light by a phosphor coating lining the inner surface of the glass envelope. Research in the last decade has led to the development of a new earth phosphor, which can provide a light of quality very close to that from an incandescent lamp, without compromising the high efficiency in converting the UV to visible light. The new phosphors also have improved performance characteristics that allow the tube diameter to be reduced to a little more than a centimeter. This in turn has lead to the development of CFLs (Gadgil & Jannuzzi 1991).

The (widespread) utilisation of CFLs can be advantageous to users of electricity, to utilities, and to the environment. An 18W CFL, for instance, provides the same light output as a 75W incandescent light bulb and can last about eight to ten times as long (Mills 1993b; Nelson 1996). Because CFLs (i) do not have to be replaced often, and (ii) use less energy, they offer significant financial savings to electricity users.[5] Depending on its rate of usage, the high first cost of a CFL could be paid back in energy savings in roughly two years. Replacing a 75W incandescent with an 18W CFL could also avoid the emission into the atmosphere of over 250 kilograms of carbon and seven kilograms of sulphur dioxide over the life of the

[4] Quoted in Simmonds (1995).

[5] In 1996 US prices, replacing a 75W incandescent light bulb with an 18W CFL could result in an ultimate saving of a typical US$33 in electricity and lamp replacement costs over its lifetime (Nelson 1996).

lamp (assuming, that is, that it conserves electricity otherwise produced in a coal-fired power plant) (Mills 1993b; Nelson 1996).

To more accurately predict the CFL-related energy savings on a global scale, detailed information about the features of different markets (usage patterns, ballast preference, rates of usage, and so forth) is needed. Borg (1994) estimates that on the very modest assumption that only 100 million CFLs replaced incandescent lamps in 1994, global sales could have yielded a 50 billion KWh savings over their lifetime (100 million CFLs @ 50W average savings/10 000 hours). This is equivalent to about $5 billion worth of electrical energy.

4. CFLs in the global market [6]

4.1 Production

Production of CFLs in 1992 was limited to the United States, Western Europe, Brazil, Mexico, Japan, Taiwan, South Korea, China and Sri Lanka. Since then manufacturing plants have also opened in Thailand, Indonesia, India, Hungary, Poland, Russia, Ukraine and Kyrgyzstan (Nelson 1996).

4.2 Sales

Though CFLs have been available for the last two decades, it is only in the last ten years that the technology has taken off (Davies 1996). Strong sales growth now characterises this energy saving technology. One reason for these rapid developments is that an increasing number of parties that were not traditionally involved in promoting efficient lighting (utilities, governments, public interest groups and others) are now active participants (Mills 1993a).

Year	*Units (millions)*
1994	200
1995	240

Table 1: Global CFL sales
Source: IAEEL newsletters (4/94; 3/96)

The figures in Table 1 point to an impressive annual growth rate. It would be unrealistic, however, to assume continued growth of this nature in the years to 2000: already the 30 per cent growth rates experienced in 1988 to 1991 have slowed to 15 per cent for 1994/5.

Compared with the sales of incandescent bulbs, unit sales of CFLs are small. Wallich (1994) notes that, if counted in units and compared to the sales of incandescent bulbs, the CFL market will paradoxically always appear small. This is because they last so much longer than incandescents. Wallich concludes that `[i]f half the light sockets in the world held CFLs, the lights would still account for only about 5 percent of bulbs sold'.

The global sales and growth distribution of CFLs is skewed. As Nelson (1996) notes:

> North America and Western Europe continue to account for more than half of global CFL sales. US sales increased by 10 percent in 1995, while those in Europe grew by 8.5 percent. However, CFLs are rapidly gaining in popularity in the former Soviet Union and developing countries, where sales growth rates are significantly higher than in the established markets. In 1995, sales increased by half in Eastern Europe and by 31 percent in

[6] Sections 4.1. and 4.2 refer to CFLs produced and sold for industrial, commercial, public and private usage, respectively.

developing countries. Latin America and the Asia Pacific region now account for 17 percent of global CFL sales.

As widespread electrification initiatives continue to occur and grow in developing countries, and as demand for electric lighting increases, it is conceivable that this distributional form will change.

It is also interesting to note that efficient lighting programmes tend to boost general CFL sales. In Mexico for instance, programme implementation has coincided with (and is probably a catalyser of) a close to tenfold growth in CFL sales in Mexico from 250 000 in 1990 to 2 200 000 in 1993 (Blanc & de Buen 1994). Similar effects have been noted in other countries.

4.3 Review of international CFL programmes

4.3.1 Introduction

Bodies seeking to introduce energy-efficient lighting into the residential sector usually do so gradually, and on a learning-by-doing basis. Most frequently, small programmes (or pilot projects) are designed and then implemented. Thereafter, larger programmes – sometimes even aimed at national level – are initiated. The infiltration of CFLs into the Mexican residential sector presents a clear case of this type of process. Prior to the implementation of ILUMEX, PAESE (an energy efficiency agency supported by Comisiòn Federal de Electricidad (CFE), Mexico's national utility) implemented at least ten pilot projects to demonstrate the technical and economic feasibility of replacing lamps with CFLs. The pilots were targeted at very specific sets of customers in different cities. One pilot targeted CFE employees (Blanc & de Buen 1994).

Projects and programmes described in this report represent those conducted and financed by various combinations of electric utilities, lamp manufacturers, lamp retailers and governments. Though utility commitment varies from country to country, utilities' presence is clear. In the Netherlands, the government has officially supported energy efficiency: a 1987 parliamentary motion on saving energy directed electric utilities to encourage the use of CFLs (Mills 1991). And, in Sweden and Austria, manufacturers of CFLs and utilities have formed strategic alliances in their efforts to distribute CFLs. In Mexico, the ILUMEX project came out of an agreement between CFE, and the Global Environment Facility (GEF) in association with the United Nations, the World Bank, and the International Finance Corporation of the World Bank Group. A similar agreement was reached in Poland, but with agreement reached with Netherlands Energy Efficient Lighting BV (NECEL) and the international lending community. In India, a consortium comprising a local utility, a potential manufacturer of CFLs, and a research institution was established, though the programme was not implemented.

It seems, from a review of the literature, that energy-efficient lighting programmes executed in developing countries experience not only similar problems to those experienced in developed countries but also a range of other problems mostly related to local circumstances. The BELLE project in India, for instance, was crushed because of infighting amongst bureaucrats and politicians and other interest parties. In general, utilities and other implemented institutions in developing countries appear to operate in more uncertain circumstances than their counterparts in developed countries – for instance, scarce public information on household lighting patterns in developing countries (Friedmann et al 1995). The following discussion, it is hoped, benefits from the experience of both developed and developing countries.

4.3.2 Motivation and form

Energy efficient lighting programmes around the world are being conceptualised and then implemented in response to the significant energy-saving (or conservation) potentials to be made (for both utilities and consumers). In the light of escalating demands for energy, it is becoming increasingly appealing that

successes should be made of these programmes, and that savings are captured for both the suppliers and demanders of energy.

Pilot programmes are designed to test the cost effectiveness and acceptability of CFLs in households. In some instances, pilot programmes have been launched with a view to specific aspects of the programme being monitored. Beginning in 1990, Mexico implemented a series of pilot projects with a view to testing:

- customer acceptance of CFLs;
- impact on the grid;
- marketing strategies;
- innovation on administrative control;
- transition to large scale projects.

	Project	*Project type or purpose*	*Lamps per customer*	*Total lamps*
1	Hermosillo I	Test customer acceptance	3 (18W)	450
2	Puebla	Test impact on grid	3 (18W)	408
3	Queretaro	Test impact on grid	5 (9W)	500
4	Valladoloid	Test marketing strategies (rebate)	up to 5	9 100
5	Chetumal	Test marketing strategies	up to 5	25 000
6	Hermosillo II	Innovate on administrative controls (rebate)	up to 5	60 000
7	Employees	Integrate personnel to conservation	up to 5	9 900
8	Guaymas	Continuation (rebate)	up to 5	15 000
9	Cozumel	Test impact on grid	up to 5	10 000
10	Aguascalientes	test sales on credit	up to 6	41 000
11	ILUMEX	large scale	up to 5	1 800 000 (expected)

Table 2: Summary of early residential projects in Mexico
Source: adapted from Blanc & de Beun (1994)

Each pilot was implemented separately and in particular order. It was decided, for instance, that before the impact on the grid could be assessed, it would be necessary to ensure that customers reacted favourably to CFLs. Similarly, marketing strategies would be tested only once utility acceptance was established. This incremental approach has proven successful though it is consuming of both time and resources.

In other instances, pilots have been implemented where variables or impacts are concurrently monitored with each pilot. In Brazil, for example, the emphasis on residential lighting pilot programmes was on a better understanding of CFLs on the distribution system, and *also* on evaluating customer reactions to the CFLs. This approach is usually adopted where there is limited scope for the implementation of numerous pilots or where there is an urgency for a large (or full) scale project.

	Implementing institution	*Type or purpose*	*Households*	*Total lamps*
'90	CEMIG (main utility in Minas Gerais State); and National Electricity Conservation Programme (PROCEL)	test impact on distribution substation; test customer acceptability	514	3 000 (9W and 13W)
'92	Sao Paulo Light and Power (CPFL) in Sao Paulo State	as above	40 (and 20 lab-tested)	400 (22W and 32W)
'93	Energy Company of Sao Paulo, CESP (state-owned utility)	test marketing strategies, utility and customer acceptability	?	9W

Table 3: Summary of early residential projects in Brazil
Source: Jannuzzi, 1994: http://eff.nutek.se/iaeel/IAEEL/newsl/1994/ett1994/PrN_b_1_94.html

4.3.3 Delivery, marketing and incentives

Utilities and other institutions around the world have chosen to distribute CFLs in a number of ways. The following are some of the approaches that have been adopted to date:

- *Give-away and free installation*

In many instances, lamps have been given away to utility customers. These give-away programmes have been conducted by mail or door-to-door visits and direct installation in homes. One of the largest give-away programmes executed in Europe took place in Denmark where 240 000 CFLs were distributed to Danish households served by the SEAS utility (Mills 1991). During Brazil's first few residential pilot programmes (1990 onwards) utilities replaced incandescent lamps with CFLs in households located close to distributing substations. The CFLs were installed at no cost to the customer. In some cases, conditions that households consent to a time period of monitoring to be undertaken by the utility once the CFLs were installed, were set (Jannuzzi 1994).

- *Survey distribution*

A survey was undertaken in 1992/3 in low-, middle- and upper-income households in Guadalajara and Monterrey, Mexico, to estimate the electricity savings potential for the forthcoming ILUMEX project (large-scale). This was done through an attempt to determine the amount, wattage, and hours-of-use of incandescent lamps that could be replaced with CFLs in the two cities. Surveyors visited participating households and, besides delivering and working through the survey material, undertook a CFL demonstration, and then presented a lamp to the customers after completion of the exercise.

- *Pricing and advertising*

Brazilian utilities have supported marketing efforts with main lamp manufacturers selling CFLs at a discount during campaigns (Jannuzzi 1994). During these campaigns, specific groups of people (mainly low- income) have been targeted.

In an article on `Some aspects of energy efficient lighting in Poland' Okolski makes reference to a `tremendous fascination [within the country] for technological accomplishments', but at the same time to an obvious absence of an energy-saving ethos. That Poland produces considerable quantities of CFLs, yet exports most of them, is manifestation of this. The Poland Efficiency Lighting Project (PELP) is now under way in the country to develop the Polish market for CFLs. The project, financed by the Global Environmental Facility (GEF), aims to replace a million incandescent lamps with CFLs in the domestic sector of Poland. The largest part of

the project funds go to the price subsidies for energy efficient lighting.[7] PELP enables Polish lamp manufacturers to claim subsidies from the project. Lamp manufacturers then pass on these subsidies to customers through reduced wholesale prices, which then translate into larger retail price reductions. Advertisements are currently running on Polish TV and radio and in the printed media. Educational material is to be provided to teachers. PELP has also negotiated with several Polish environmental and consumer non-governmental organisations to try to disseminate news about the benefits of CFLs (Granda & Rijntjes 1995). Interestingly, PELP has preceded the establishment of any official utility DSM programme in Poland.

In the city of Valladolid in Mexico, a large exposition (with four CFL manufacturers) was held in the centre of town in the early '90s. The marketing strategy included the distribution (with electricity bills) of brochures providing information on CFLs, a programme for and invitation to the exposition, and the location of the places where the lamps were going to be sold. The exposition was opened with great media coverage by local and CFE authorities. At the show, customers were issued with rebate forms and instructions about processing them (Blanc & du Buen 1994).

- *Rebates*

In the United States, Boston Edison Company's (BECo) efficient lighting programme allows customers to participate in three ways:

- Customers can purchase any qualifying lighting products at a local retail store and then mail in a rebate form along with proof of purchase.[8] With some lag time, BECo then issues cheques to the customer.
- Customers choose a product and the rebate amount is deducted at the point of purchase. The customers must purchase the lighting device at participating retail stores, which include BECo's eight Energy and Environmental Centres, two electric supply outlets, as well as two independent retail outlets. These outlets would also supply advice and information to interested parties.
- Lions Club members conducted CFL sales door-to-door during a special promotion, the Lite for Sight programme (Results Centre 1992).

Various utilities in China recently began to offer these rebate-types to residential households too (Fu Min & Mills 1994).

On Guadeloupe in the Caribbean, the state-owned utility, Electricité de France, with the help of the French Environment Protection and Energy Management Agency (Ademe) launched a CFL programme in the early 1990s. The programme included the utility sending customers rebate coupons good for up to ten CFLs at a special price (one third of the normal retail price). The rebate mechanism allowed customers to spread the payment of their CFLs over six sequential utility bills (18 months). The payment amount was also set such that energy savings for lamps used for four hours a day or longer would be greater than the lamp payment. Participating retail stores were stocked with 15W electronic CFLs. Shop owners received a small rebate for each CFL sold (Mills 1992). The Pacific Gas and Electric utility programme in northern California utilises a similar approach to this (Gadgil & Jannuzzi 1991).

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[7] Price subsidies are important in the short term because CFLs presently cost more in Poland than in OECD countries.

[8] Rebate forms and programme brochures are provided to participating retailers by BECo and the materials are generally displayed alongside eligible products.

- *Warranties*

A manufacturer warranty concerning the life of CFLs could help to allay the worries of customers that the lamps will not last long enough to justify their high cost, or that they will fail during usage. This is a particularly useful instrument, particularly if targeted towards the risk-aversity characteristic of low-income customers. Such warranties have been a success in Germany (Kofod 1996).

- *Pay-on-the-bill*

In the Netherlands, households obtain their lamps at retail stores, but the payment is made over the course of a year via their utility bills (Mills 1991). Similar schemes have been undertaken in Thailand, Ireland, Germany, France and Sweden (Mills 1993a). The pay-on-the bill (or charge-on-the-bill) programme in Thailand will distribute some 1.5 million units, with an additional several hundred thousand targeted for low-income households (Nelson 1996).

- *Leasing*

In Bombay, India, the Bombay Electric Lighting Large-scale Experiment (BELLE) was designed to introduce energy efficient lighting to the poor and, in so doing, to plan towards a reduction in peak evening demand. Through BELLE, a 60W incandescent lamp would be replaced with a 15W CFL fitted with an electronic ballast (a greater light output). It was planned that CFLs be leased to BELLE participants under a four-year leasing scheme for residential customers. Lease payments were designed to be smaller than the reduction in monthly electricity bills: customers would save Rs106 per year respectively through lower overall electricity bills and avoided incandescent purchases. In addition, lamps would be fully paid for within a fraction of their expected installed life. The lease could be terminated at any time by the customer returning the CFL to the utility.

In Vermont, United States, the Burlington Electric Department (BED) launched the Smartlight programme whereby residential customers have been able to lease any of BED's compact fluorescent lamps for a small amount each month (20 US cents in 1992).[9] For any lamps used for one and a half hours a day or more, leasing is a breakeven or better financial proposition. After 60 months (or $12 worth of payments), the lease fee stops, effectively completing the customer's payback of the lamp. If a bulb breaks or burns out, upon return to BED the lease fee stops. A new bulb, with a new lease, is then issued. If customers do not like the bulb, it can be returned at any time and the lease stops. A two-month break-in period is given before the lease starts, so customers need not pay until the device has been tested and accepted. If the customer moves, the lease fee is stopped whether the bulb is returned or not (Results Centre 1992). More recently, a similar campaign was launched in Austria (Borg 1995).

This scheme is also offered by the US utility Tauton Municipal Lighting Plant, which offers to lease the lamps to the customer – if necessary, in exchange for a coupon that the utility mails also with the monthly bill. The utility then recovers the rent on the subsidised lamp by adding an amortised amount to the monthly bill (Gadgil & Jannuzzi 1991).

- *'CFL boxes' and Energy Centres*

In 1994, the Austrian Association of Electric Utilities together with a number of CFL manufacturers launched a 'hands-on' lamp information programme. This programme entailed the preparation of boxes containing eight or so commercially available CFLs (ranging from 9W to 24W) which customer could borrow free of charge for a few days to test the various lights in their home environment. The

[9] BED's intent with the lease mechanism was to give people a sense of ownership of their actions, to insure that the bulbs were installed and used in cost-effective applications. Recouping cash was low on BED's list of objectives.

purpose of these programmes is to help to remove the psychological barriers against CFLs, such as uncertainty about the technology in combination with high initial costs. Also, when household customers return the lamp-boxes together with a questionnaire, the utilities have an opportunity to further discuss how to use electricity and energy more efficiently. The programmes have not focused on moral (environment-friendly) or rational (money-saving) appeals. Instead, the programmes' sole intention has been to motivate customers to compare the quality of light of CFLs with that provided by incandescent lamps, and to see whether CFLs fit into their home environment. The programmes, never intended to be once-off but rather continuing initiatives, have been very successful to date. There has been a remarkably high degree of acceptance of the programme: most of the borrowers responded that they would like to install CFLs in their homes (Borg et al 1995).

In Denmark, a similar programme has been run over the past few years. Lamp boxes are available for borrowing at Energy Centres (which provide advice and information on energy-efficient technology and use, particularly for the household sector) .and utilities around the country. Borrowing institutions do not require customers to leave a deposit but stipulate that boxes must be returned on time. If the CFL collection returns incomplete, or is damaged, lamps are replaced by the utility without asking questions. In addition to the lamp boxes, customers can borrow portable meters which they can use to measure the energy lamps (and other household appliances) are individually using.

- *Sectoral targeting*

Southern California Edison (SCE), a leader in DSM in the United States, supports community-based organisations which conduct the promotion and delivery of the Relamping Programme (one of nine programmes included in SCE's Customer Assistance Programme). To qualify for the programme, and thus for the service, customers' household income must not exceed 150 per cent of the poverty level as defined by the Federal Health and Human Services Department (or 200 per cent for handicapped persons and senior citizens). Services, performed in a single home visit and at no charge to the customer, include: (i) replacement of as many as six incandescent lamps (identified with highest wattage and longest duty cycle); (ii) a simple energy audit, and; (iii) an energy efficiency session (Results Centre 1992).

- *Internal marketing*

In Mexico, a programme has been designed to integrate personnel of the national utility, Comisiòn Federal de Electricidad (CFE), into its energy conservation efforts. During a five-month campaign, CFE invited several CFL manufacturers (only one manufacturer accepted the invitation) to their offices to sell lamps to personnel. Each employee was given a credit of about $US130 with which lamps of his/her choice could be purchased (on signing a document and handing over the credit note) from various stand operators. Weekly, the lamp operators collected payment of purchased CFLs. Employees paid for the lamps through discounts in bi-monthly cheques. In the course of the programme, 9 900 CFLs were sold (49 per cent were 13W; 36 per cent were 9W; 9 per cent were 15W; and 7 per cent were 11W) (Blanc & du Beun 1994). No evaluation of this programme was done.

- *Other economic instruments*

Tax rate instruments are important incentives to promoting the diffusion of CFLs. In their article, `Conservation potential of compact fluorescent lamps in India and Brazil', Gadgil and Jannuzzi suggest that the lifting of heavy customs duties on imports of capital equipment for manufacturing in India could be carried further in terms of eliminating excise duties and sales tax on CFLs. This has been achieved with much success in Pakistan (Mills 1993c).

4.3.4 Critical success factors

> [M]uch remains to be understood about effectively marketing lighting programmes. The striking lack of correlation between the level of program costs and participation rates suggests that 'throwing money at the problem' is not enough. Successful programmes must offer an adequate financial incentive and employ effective market strategies (Mills 1993a: 141)

In general, utilities and other bodies interested in encouraging the usage of energy-efficient lighting devices have found that marketing is a vital element of the overall process. Barriers to entry into the market are pronounced and will be discussed in greater detail in a subsequent paper in the energy-efficient lighting series. Suffice to say, people are often not aware of energy-efficient lighting, and need to be informed about it. In some instances, it has been determined that people's conception of energy-efficient lighting is incorrect. Results of a survey conducted in Poland, for instance, indicated that, within a group of residential customers, energy-efficient lighting had been reduced to the incorrect notion that energy-efficient lighting means saving the light. Thus the average customer installed bulbs of lesser power, thus worsening the quality of the light produced, rather than replacing these lamps with more efficient light sources which allow for the saving of energy without a change in lighting conditions (Okolski 1995). Following this notion, customer efforts to save energy also involve turning lights off more often than normal habit would entail. And a survey conducted in China found that typical Chinese customers often view energy-efficient lighting as something that saves energy but not money. When buying cheaper but poorer quality products, some consumers lose all confidence in the technology (Fu Min & Mills 1997). Lastly, when the price of electricity for individual households is low enough not to promote energy-saving activity, it is not rational for customers to buy relatively expensive energy-efficient lighting devices.

In an article entitled `Efficient lighting programmes in Europe: Cost effectiveness, consumer response, and market dynamics', Mills notes that: `[i]nformation alone is a weak tool for promoting energy efficiency. Participation rates are seen to be significantly lower and overall lamp costs higher when utility efforts are focused only on providing consumer information'. Mills gives the example of a programme conducted in Schleswig-Holstein where an intensive information effort, focusing on environmental benefits of using CFLs but offering no financial incentive, was conducted. The impact of this programme (CFLs/eligible household) was one tenth that of similar financial incentive programmes undertaken.

4.3.5 Institutional and organisational support

International experience points to a clear need for strong institutional building efforts to be undertaken by utilities or bodies undertaking energy-efficient lighting initiatives. Besides utilities undertaking normal day-to-day procedures, these efforts are necessary in order that capacity be available to:

- offer readily forthcoming technical, and informational support to customers and (potential) manufacturers;
- monitor and evaluate programme initiatives;
- develop procedures and policies on energy efficient lighting (including incentives, tariffs, regulatory mechanisms and standards); and
- co-ordinate between relevant parties (utilities, governmental and international interests, end-users, and manufacturers).

The following instances, among many, serve to note the importance of this:

- The market potential for CFLs in China is indisputable. There is, however, a lack of clear direction and comprehensive policy from central and local governments in the country regarding energy efficiency and lighting. Through the support they are offering to manufacturers, utilities in China are partly compensating for this policy vacuum. Largely as a result of this, manufacturers

are beginning to place more importance on the *quality* of products (Fu Min & Mills 1994).

- In India, manufacturers who have been considering CFL promotion in the country are, despite the huge potential market, uncertain about the willingness of the market to adopt CFLs on a large scale (Gadgil 1993). Utility structures can facilitate this investment process, by providing knowledge (through lighting programmes) about the market's potential to absorb this technology.

4.3.6 Participation and customer response

Mills (1993a) points to an interesting finding in Europe that efficient lighting programmes have opened up markets and increased the rate of market penetration for CFLs in the domestic sector where manufacturers previously saw little or no market. This finding appears to be common to other countries too, and points to the notion that the manner in which programmes target consumers is important. Seemingly, no particular income sector, gender group, or other social stratum, should be disregarded by utilities and manufacturers on the grounds that the market is not sufficiently large enough to warrant an intervention, since a market may develop. This is also not to say that it is in the interests of utilities and manufacturers to promote energy-efficient lighting to customers as if they were a homogeneous group. To the contrary, Almkvist (1991) suggests that the tendency of utilities to take the approach of failing to segment the market according to likely consumer needs and motivations is undoubtedly a widespread problem.

Participation rates reflect the importance of demographic factors being taken into account in utilities' programme designs. A study undertaken in Sweden, for instance, showed that pensioners represented a greater proportion of programme participants than they represented in the eligible populations: 44 per cent versus 26 per cent in the Stockholm Energi programmes, and 38 per cent versus 27 per cent in the NUTEK programmes. Single-family households also represented a greater proportion of programme participants than they represented in the eligible populations: 37 per cent versus 12 per cent for the Stockholm Energi programmes, 63 per cent versus 49 per cent for the NUTEK programmes, and 63 per cent versus 33 per cent for the Malmo Energi programmes (Mills 1993a: 137).[10] Furthermore, a study of the NUTEK (Swedish) energy-efficient lighting programmes indicated that women had a more positive reaction to the programmes and were more willing to invest in energy efficiency (Millsa 1993). Interestingly, in Poland it has been found that men are filling this role! (Okolski 1995). Okolski also notes that in Poland there are a `wide range of attitudes' towards the energy efficient lighting but `generally, people who are more educated, better-off, and younger' share the greatest interest. Perhaps, in this regard, Gadgil and Jannuzzi's (1991) appeal to treat efficient lighting programmes on a case-by-case basis (thus taking into account the individualness of contexts) and multi-pronged (accounting for different peoples' different needs), is worthwhile. A learning-by-doing and trial-and-error approach (contextual planning) might also help to tailor programmes for local circumstances (Friedmann et al 1995).

The number of people choosing to participate in an energy efficient lighting programme (that is, installing CFLs in the domestic environment) is clearly a function of the extent to which the programme is known and is deemed acceptable by eligible parties. Acceptability, in turn, is a function of a spectrum of factors, the most predominant of which are listed and briefly described below:

- *Pricing*

Mexico's national utility, CFE, announced a number of years ago that it would be gradually reducing the subsidy it allocates to the price of electricity in the country, and would, instead, move to pricing based on the long-run marginal cost of

[10] The degree to which this reflects differences in factors such as income, renter-vs-owner tenure, or other variables has not been investigated.

electricity. This intention, supported by the Global Environment Facility of the World Bank, was reached as part of its large-scale move towards the promotion of energy efficient-lighting in Mexico and particularly in its largest cities – Mexico City, Guadalajara, and Monterrey. CFE envisages that higher rates will lend support to its CFL and DSM programmes which, in turn, will help to plan for these rate increases (by using less energy even for the same output) and thus mitigate rate shocks experienced, in particular by low-income households.

International experience has shown pricing policies to be of utmost importance in the strategic planning processes of energy efficient lighting programmes. As noted earlier, it is not in the interest of residential customers to invest in energy-saving measures if the price paid for electricity is low (below the long-run marginal cost of electricity). This is especially true if alternatives to normal energy usage are costly. Perhaps most striking in energy-efficient lighting literature (particularly that detailing programmes in developing countries and the low income sector where high discount rates for future savings in energy efficiency are experienced) is the concern about low participation rates in programmes due to the initial high start-up cost of energy-saving lighting devices.[11] In the city of Valladolid in Mexico, for example, 60 per cent of those interviewed during a survey to determine why CFL sales were so low (given that the utility had three months previously held a well attended efficient lighting exposition in the town centre) argued low incomes and high lamp prices as the reasons for not buying CFLs. Similar problems have been experienced, and documented, in Thailand, India, Brazil, China and parts of Europe.

- *Form of incentive and purchasing scheme*

High lamp prices represent one of many forms of barriers preventing entry into the energy-efficient market. As noted above, in the section on marketing and incentives, financial incentives to mitigate this barrier are critical to the success of CFL programmes. The form of the incentive is also an important determinant of the programme participation. During given periods in Denmark and the Netherlands, for instance, consumers were given the opportunity to pay cash for the CFLs they purchased or to pay gradually via their utility bills. In each country, approximately three quarters of the participants preferred to purchase the devices with periodic payments to the utilities. In fact, Danish customers paying over a period of three utility bills bought five CFLs in 60 per cent of the cases, whereas consumers paying in cash bought five CFLs in only about 15 per cent of the cases (Mills 1993a).

In Mexico, a survey undertaken showed different results: a significant number of Guadalajarans interviewed expressed a preference for buying CFLs outright rather than entering into a lease/rent scheme. This, it has been suggested, is an indication of Guadalajarans' distrust of official government. A similar survey undertaken in Monterrey suggested that, in general, customers in this city prefer financing schemes (Friedmann et al 1995). These results lend support to the contention that custom-made programmes are vital to the success of any initiative.

- *Light output*

In the early days of development, the quality of light CFLs emitted was noticeably different from that of incandescent lightbulbs. CFLs tended to flicker on start up, and the light then emitted was, generally described as being cold or artificial, and inappropriate for the residential sector. This radically affected participation rates in many of the early energy-efficient programmes. With rapid technological advance and diversification, this is becoming less of a concern for potential programme participants, as are CFLs' capacity to be dimmed.

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[11] See for instance Blanc and du Beun (1994), Gadgil and Jannuzzi (1991), Fu Min and Mills (1997), Okolski (1994), Kofod (1996), and Mills (1991; 1992; 1993).

Where CFLs are being used to replace incandescents (and therefore not necessarily in newly electrified areas) some concern is being expressed at the amount of light that CFLs are putting out. From the utilities' point of view, the lower the wattage the better (higher wattage means lower reduction of kW of peak power demand and less energy saved). In many instances though, participants have commented that they are not receiving as much light as they used to with incandescents, and note a strong preference for greater light outputs. With given parameters, and products to choose from, 86 per cent of customers interviewed in Mexico expressed a strong interest in obtaining 22W lamps, while only a small percentage preferred 13W lamps, and even fewer preferred 9W lamps (Blanc & du Beun 1994). These findings concur with those in most other countries.

- *Quality of device*

Even though most utilities and CFL manufacturers guarantee to replace any units that do not operate on purchase, or cease to work in the first few months of utilisation, it has been shown that participation in energy-efficient lighting programmes can be severely dampened (or at best waylaid) if lamps are seen to be ineffective (Kofod 1996). This happened in Ireland when the national utility recently purchased Chinese-made CFLs for a pilot rebate programme. The CFLs had the best power quality characteristics of any to be found on the international market, but unfortunately the early failure rate was about 25 per cent. The CFLs were rejected by both the utility and participants in the pilot programme (Fu Min & Mills 1997). Though it is too soon to determine whether these defects have had significant impact on customer attitudes, it is certain that the quality of Chinese lighting products will now be scrutinised perhaps more closely than normal.

- *Availability*

Availability of lamps has often been a limiting factor to the success of lighting programmes. Retail outlets and utilities are frequently unaware of, or underestimate, the response to a planned utility programme, and do not have adequate stocks. As a result of a global shortage of CFLs (Mills 1991), large orders need to be placed well in advance of programme implementation – often so that the lamps can be assembled or even manufactured. Thus, if stocks are depleted, it generally means that the benefits of the programme will be forfeited. Potential customers cannot participate, and lose interest if expected to wait for new stocks.

Though China and Poland are large producers of energy-efficient lighting, export incentives are favourable enough that domestic energy-saving potentials are not captured in an significant way. Interestingly, utilities operating in these countries have recently been experiencing difficulties (of notable proportions) in obtaining CFLs. In Europe, local manufacturers have not even saturated the regional market. In this regard, it can be said that even countries that manufacture energy-efficient lighting devices locally are susceptible to shortages.

- *Cultural norms*

Often the extent to which households participate in energy-efficiency lighting programmes is a function of local fashions, cultures and norms, and no matter how the programme is marketed, a wider market remains unpenetrable by the utility or CFL manufacturer. An example of this comes from India, and is well documented in Gadgil and Sastry's 1994 paper 'Stalled on the road to the market'. In summary, the authors suggest that 'cultural aspects of decision making need to be taken into account', for the roles that institutions were playing in India were being 'defined by their actions rather than by their stated purpose'. In this regard, internal and politically and bureaucratically motivated practices[12] (which seem to be viewed as standard practice in India) severely obstructed what appeared to be a cost-

[12] Steep hierarchical structure of institutions, few opportunities for project support, and intense fighting for niches (Gadgil & Sastry 1994).

effective, no-regrets approach to uplifting conditions for the world's poorest citizens and at the same time making a contribution to the reduction of global climate change. The authors conclude that `the weak element of [the] organisation of the project was [the] underestimation of the power of behind-the-scenes caucuses against the project and of the importance of identifying and energizing potential champions of BELLE in the invisible power network of the bureaucracy and politicians'.

Another example: most residential lighting installed in Thailand in the past has been of the more efficient fluorescent type. Unfortunately for utility planners, new houses in the country are moving towards increased installation of incandescent lighting (IIEC 1991). Building fashions/trends have signalled this trend.

Finally, most societies include people who are open to new technology, and others – `technology laggards' – who prefer to continue to operate familiar, usually less technologically advanced, devices. Changing to CFL technology is representative of a significant movement, and one which some are unable or unwilling to make. No matter how sharp or attractive the marketing might be, it may not be enough to convince customers. In developing countries in particular, this phenomenon might be perceived to be a desire to maintain momentum as just described. In some instances further investigation has found that the required change is one which restricts, curtails, or clashes with acceptable cultural or income-related behaviour. Examples of this relate to the use of open fires for heat, light and socialising, and to the use of incandescent light bulbs for warmth – neither of which are substitutable by CFL technology.

- *Education*

The importance of informing and educating potential users of energy-efficient lighting has been mentioned above, in the section on marketing and incentives, and thus does not need to be re-iterated. Suffice to say, it has been found that information and education is a vital element of any energy-efficient lighting programme: it helps to counter misconceptions about energy efficiency and energy efficient lighting, and it serves to inform customers about new technology that they might previously have been unaware of. Without this, utilities cannot expect a satisfactory rate of participation. Also, the type of information and the manner in which it is relayed will have impact on the extent to which the programme is well received. Misleading elements of an ill-conceived Polish TV advertisement designed in response to the 1973 oil crisis to campaign for the efficient use of energy in Poland still has effect today (Ololski 1995).

- *Institutional support*

Results of numerous surveys conducted in Europe and Mexico indicate that, in general, CFL users would like to be supported (or would like to know that support is unconditionally available to them if they so require), not only at the time of purchase of their units but also for an extended period of time afterwards. Concern has been expressed for the many utility programmes that have been once-off initiatives (Mills 1991; 1993; Friedmann 1996). In this regard, customers have expressed a view that they would be more willing to buy CFLs on a more consistent basis if they can be assured that they will not be let down by the `new technology' and that the high start-up costs prove worthwhile.

5. Conclusion

Perhaps the most profound lessons coming out of a review of CFL programmes in an international context is the critical need for utilities, or other bodies fulfilling similar roles, to design and implement energy-efficient lighting programmes based on local circumstances, and needs. Policy and practice that have worked (and seem to present no-regrets options) in some environments has been the reason for the demise of programmes in other areas. This call for customised initiatives is indicative of the importance of

i. extensive local research;

ii. the adoption of a learning-by-doing approach; and

iii. dialogue and cooperation between all the parties involved: CFL manufacturers, retailers, designers/architects, utilities, government agencies, and customers.

International literature also refers frequently to the need for programmes to be designed around a balance between marketing and financial incentives. Both are necessary but not individually sufficient to ensure the success of such programmes.

Finally, though the cumulative result of experience in energy-efficient lighting practices in different parts of the world has been rich, options for the further development of this sector have in no way at all been exhausted. A review such as this should, therefore, not limit future DSM and end-use activity. In order that the full saving potential of this technology is achieved, it is vital that more lateral and innovative thought is applied.

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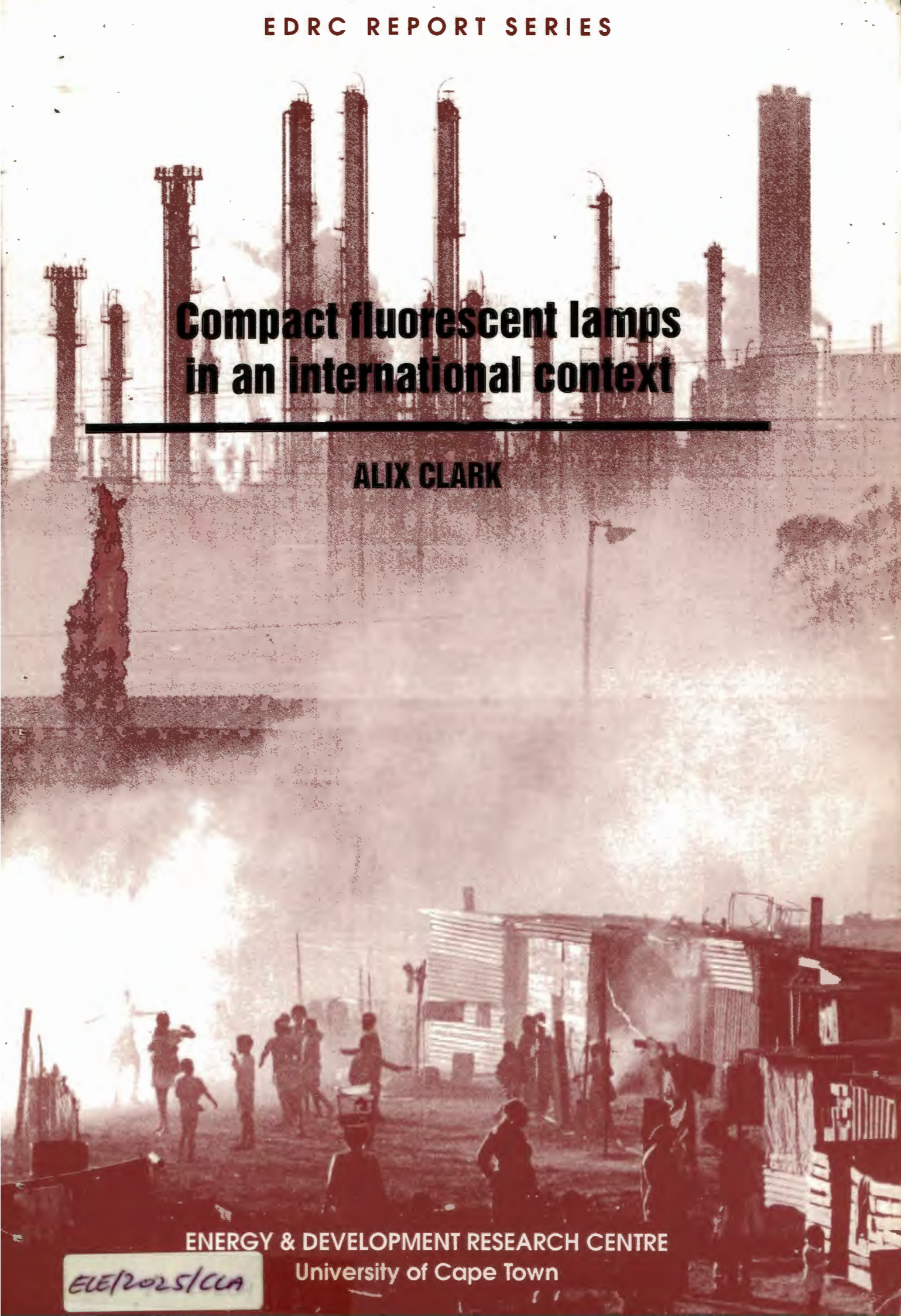

Compact fluorescent lamps in an international context

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