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Energy-efficient lighting programs

Experience and lessons from eight countries

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We analyze ten case studies of energy-efficient lighting programs in eight countries – Poland, Thailand, Mexico, Jamaica, Peru, Brazil, Denmark and the United Kingdom – to draw out and compare the lessons and experience related to program approaches, technology diffusion and market transformation impacts, cost effectiveness of greenhouse-gas reductions, and economic benefits. Program approaches include direct subsidies, wholesale buy-downs, bulk procurement, give-aways, education, voluntary agreements, and consumer financing mechanisms. All approaches were adequate to deliver a targeted quantity of high-efficiency lamps to consumers, but differed substantially in their cost-effectiveness, economic benefits and market transformation effects. The Poland, Thailand, Danish and UK cases in particular show that lighting programs can reduce CO_2 emissions at a cost of US\$5–US\$10/ton, or even less including indirect impacts. The potential indirect impacts on national lighting markets through the market transformation aspects of the programs are significant but difficult to assess because of the absence of pre-project baselines. The cases focus mainly on compact fluorescent lamps (CFLs) for residential use, and include four recent projects financed in part by the Global Environment Facility.

Keywords: Energy efficiency; Market transformation; Compact fluorescent lamps

Introduction

In recent years many energy-efficient lighting programs have been conducted worldwide by multilateral agencies, government agencies, and non-governmental organizations. Many of these programs have been called 'market transformation' programs because they attempt to alter the fundamental structure of the lighting marketplace in a particular country or region (Geller and Nadel, 1994). In this paper, we analyze ten case studies of energy-efficient lighting programs in eight countries. In particular, the Global Environment Facility (GEF) has funded four recent energy efficiency projects with lighting components in Poland, Thailand, Mexico, and Jamaica.[1] Other notable programs have been completed in Peru, Brazil, Denmark and the United Kingdom.[2] Although many other papers have analyzed individual programs, there have been fewer cross-comparisons among programs. The case studies provide a catalog of proven market transformation approaches for promoting energy efficient lighting and an analysis of their cost-effectiveness, and provide a wide cross-section of approaches, experience, and lessons for promoting energy efficient lighting. The review focuses mainly on programs to promote compact fluorescent lamps (CFLs) for residential customers because this has been the focus of the GEF programs.

Global markets for CFLs are expanding rapidly and prices are decreasing. More manufacturers are entering the market, including European firms and an estimated 1000 Chinese CFL manufacturers in 1997 (up from 500 in 1995). Chinese production alone was estimated at 100 million in 1997, about 20–25% of global production (Chen, 1997; Hong, 1997). With the increasing number of manufacturers and production capacity, and the fact that several CFL patents are about to expire, prices have begun to drop. IKEA, one of the world's largest furniture department store chains with outlets in 28 countries, has started to sell Chinese-made CFLs that meet quality and performance standards (under a Danish and Swedish

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[1]The World Bank is the GEF Implementing Agency for the Poland, Thailand, Mexico, and Jamaica projects. In some of these projects, the World Bank, other international donors, and/or the private sector have provided additional financing.
[2]China also deserves special mention although we do not cover Chinese programs here; see Nadel *et al* (1997).

testing program) for US$5 apiece in Scandinavia (Lundberg, 1997; Persson, 1998). Other department stores are reportedly lowering their prices of quality CFLs in response to IKEA's move. For example, a Danish department store now sells quality, imported CFLs for about US$7.50 (Kofod, 1998). In France, an independent CFL producer was to start a CFL production line in late 1998 with an annual output of more than 10 million units. These CFLs would use a new power supply unit that could inherently reduce size and costs, and the CFLs are expected to retail below US$6 (Phone Tiang, 1998). With these trends, quality is becoming a major issue. As more and more manufacturers enter the market, consumers will find it increasingly difficult to tell low-quality from high-quality lamps, and the reputation of CFLs could suffer as a result.

This global situation provides a framework for assessing program strategies. Programs in a particular country or region should be designed to set the national or regional market in the right direction for integration with the maturing global market. The case studies and general industry experience show that the right direction features three main strategies: (i) raising consumer awareness and information; (ii) creating and strengthening effective distribution channels; and (iii) improving product quality and building the necessary domestic and regional institutions for quality management, testing, and product standardization. In mature CFL markets with decreasing prices, such as in Scandinavian countries, direct subsidy programs become less important in facilitating these strategies. But in immature markets, such as in many non-OECD countries, properly designed subsidy programs can be an important and cost-effective tool for moving markets in the right direction, and in helping markets mature to the point where subsidies become less important.

Program descriptions

Below are brief descriptions of the ten lighting programs analyzed in the paper.[3]

Mexico high efficiency lighting project (1993–1995)

Under this project, the national electric utility (CFE) purchased CFLs and sold them directly to consumers through its offices. The utility purchased the CFLs in bulk under competitive procurement from manufacturers, receiving a significant discount over retail market prices. The programmatic approach was essentially a utility DSM program with extensive consumer marketing and outreach. The project took place in two states in Mexico, Nuevo Leon (capital Monterrey) and Jalisco (capital Guadalajara). These two capital cities are the largest in the country that the national electric utility serves. Low-income consumers were particularly targeted, because of the large subsidy paid by the utility for electricity purchased by these consumers (Friedmann, 1996 and 1998; Friedmann *et al*, 1995; Sathaye *et al*, 1994; GEF, 1994).

Poland efficient lighting project (1995–1997)

This private-sector project was designed to stimulate the national market for energy efficient lighting in Poland and accelerate the market by five years through four components: (1) CFL subsidies were provided on a competitive and contractual basis through manufacturers to reduce wholesale prices to dealers and retail prices to consumers (also called 'wholesale buy-down'). Manufacturers competed to provide the largest guaranteed sales at the lowest project subsidy cost, and contributed additional price reductions themselves. (2) A pilot peak-load-shaving DSM program in three towns was conducted by municipal governments and local electric utilities. Through a special promotion program, discounted CFLs were sold to residents in specific districts where peak electric capacity was constrained. (3) A wholesale buy-down was also conducted for CFL luminaires. (4) A public education program, with the participation of non-governmental organizations, created a special logo to promote CFLs, conducted television and press advertising campaigns, and conducted an energy/environmental education program in over 250 primary and secondary public schools (Granda, 1997 and 1998; Jarosz, 1997; NECEL, 1997a, b; EEI, 1997; Tulej, 1997; GEF, 1996).

Jamaica demand side management demonstration project (1995–)

This project created a DSM program unit within the Jamaica Public Service Co (JPSCo) utility and is demonstrating a broad-based utility DSM program. As part of this program, the utility gave free CFLs to 100 homes (about 300 lamps) to test them and to establish technical criteria regarding equipment performance, customer response, and installation problems. Subsequently, the utility has begun to sell a planned 100 000 CFLs to approximately 30 000 households at discounted prices. The utility sells CFLs to consumers as part of an overall energy savings package along with combinations of other equipment like low-flow showerheads and outdoor lighting controls. Consumers have the option of paying cash or applying for financing with 12 monthly payments through electricity bills. The program also involves a substantial public education and information

[3]Published sources for the case studies, where available, are given in the references. Sources of information for the Mexico and Thailand case studies include internal World Bank documents and personal communications with World Bank staff. Sources of information for the Poland case study include internal International Finance Corporation (IFC) documents and personal communications with IFC staff (the IFC was the GEF Executing Agency for the Poland Efficient Lighting Project). See also GEF (1998) for descriptions and evaluations of GEF projects.

campaign through utility mailings, offices, and the media (Harris and Titus, 1997; GEF, 1992).

Thailand promotion of electricity efficiency project (1993–)

This project is a comprehensive five-year utility DSM program by the national electric utility responsible for power generation (EGAT). The DSM office is developing and implementing a number of different market intervention strategies for energy efficiency. EGAT was very keen in this project to avoid subsidy programs, and instead has tried to rely on voluntary agreements, market mechanisms, and intensive publicity and public education campaigns. Under a high efficiency fluorescent tube program, EGAT elicited a voluntary agreement with all five Thai manufacturers and the sole importer of T-12 fluorescent tubes to switch from producing and importing T-12 tubes to T-8 tubes. Under a CFL program, EGAT is purchasing in bulk a planned 1.5 million CFLs and selling them through a distribution network of '7–11' convenience stores. EGAT also expects to promote low-loss magnetic ballasts through bulk procurement (Ratanopas, 1997; GEF, 1993).

Brazil CFL residential lighting pilot programs (1993–1996)

A number of the large Brazilian utilities have conducted pilot CFL dissemination programs to research marketing approaches, consumer behavior, and T&D system impacts. In its first pilot program, CPFL (São Paolo Light and Energy Company) tried three different rebate levels in three different cities, respectively: 30% (Americana), 60% (Marília) and 70% (Franca). Rebate coupons were mailed directly to consumers and the utility ran a marketing and information campaign which was similar for the three cities. The coupons entitled consumers to buy up to three lamps at a reduced price. The programs were small: only 10 000 lamps in each city for each rebate level. In a second program, another utility, CEMIG (Minas Gerais State Energy Company), tried a direct-install, give-away CFL program in an impoverished region, *Vale de Jequitinhonha*, which experienced frequent brownouts. The utility gave away 89 000 9-W CFLs to 52 000 households that had an energy consumption below 50 kWh/ month. Through the program, the utility hoped to improve voltage and current levels in the distribution systems, and thus help all customers obtain more acceptable lighting service levels and lower risks of damage to appliances (Jannuzzi *et al*, 1997; Jannuzzi, 1998; Geller and Leonelli, 1997; Geller *et al*, 1997).

Peru national energy saving campaign (1995–1996)

Peru implemented a National Energy Saving Campaign with the aim to reduce electric demand by 100 MW during peak hours. Electricity consumption had grown quickly during the economic boom in 1993 and 1994, and very low levels of rainfall during the last months of 1994 had affected the country's hydropower system badly. The campaign was launched by the Ministry of Energy and Mines with a sense of urgency. An aggressive energy efficiency campaign was seen as the only option available in the short term. An initial plan for a CFL give-away program was rejected by the government because it wanted to promote a 'free-market' approach. Instead, the campaign included only public information, education, demonstrations, and a CFL replacement program but no subsidies. A small-scale pay-on-the-bill program was also conceived, in which consumers purchased CFLs through 24-month installment plans: consumers purchased lamps in shops with special coupons from their electricity suppliers, and the cost of the lamps was added to their electric bill in installments (Romani-Aguirre, 1996).

UK energy saving trust CFL programs (1994–)

The Energy Saving Trust (EST) was established in 1992 by the UK government and the gas and electric utility industry, in part as a vehicle for implementing the government's CO_2 reduction policy in response to the Rio Summit. Since the utility industry was being privatized and deregulated at that time, and thus increasingly focusing on low electricity tariffs, the government could not rely on traditional DSM programs to implement energy efficiency. The Trust acts as a non-profit company and is funded by the government and the utility industry. EST conducted several lighting programs between 1994 and 1997, including subsidies through a manufacturer rebate mechanism and give-away programs. Rebates were offered to consumers in the form of a price reduction at the point of retail, including a matching subsidy by the manufacturer. In the give-away program, 800 000 households received a 20-W CFL to replace a 100-W incandescent GLS lamp. The CFLs were part of a package of the Home Energy Efficiency Scheme (HEES) tailored to poor households (Heywood and Rowe, 1997a, b; Heywood, 1998).

Danish residential utility DSM and quality programs (1988–)

Denmark now has the second highest CFL ownership rate in the world (second only to the Netherlands) (DEFU, 1996). Between 1988 and 1994, Danish utility programs deployed about 1 million CFLs through a combination of give-aways, pay-on-the-bill sales, and (most commonly) sales through rebate coupons. In the later programs, subsidies were lower and finally phased out. Since 1994, Danish CFL programs have moved away from rebate programs towards an increasing focus on quality, testing and labeling (DEFU, 1996; Pedersen, 1997). An extensive but relatively low-cost CFL quality program has resulted in a very low market share of low-quality CFLs – only 5% compared to 30–40% in Germany, for example (Pedersen, 1997; DEFU, 1996; Kofod, 1998; Lund, 1998).

Market barriers and program approaches for overcoming them

The case studies highlight nine principal barriers to expansion of CFL markets:

- Lack of information and conviction by consumers about the benefits of CFLs.
- High first-cost of CFLs (high consumer discount rates), compared with standard bulbs.
- Lack of low-transaction-cost credit mechanisms in markets with low per-capita incomes.
- Lack of manufacturer initiative to expand markets due to low consumer demand.
- Lack of institutional capacity within electric utilities to carry out DSM programs and to market energy-efficient technologies.
- Lack of understanding by government regulatory agencies about the opportunities and benefits of energy efficiency, and thus reluctance to approve energy-efficiency investments and create new regulatory incentives.
- Early product failure and poor product quality.
- Lack of compatibility with existing luminaires.
- Intangible consumer-preference factors, including disappointment with performance (other than lamp life) and aesthetics.

In non-OECD countries with immature markets, the first three barriers (information, first-cost, and credit) are especially significant, although all the barriers are important. To overcome these barriers, especially the first three, the main CFL program approaches taken have been a combination of subsidized retail prices, creation of new distribution-system innovations or capacities, new financing mechanisms, and consumer education and information campaigns (see Table 1).

The Peru and Thailand cases are examples of programs without direct price subsidies. In the Peru case, consumers bought 380 000 CFLs for cash over a short time period based solely upon a massive four-month publicity campaign. But this campaign was quite expensive (several million dollars) and not as cost-effective as other programs studied that did have subsidies (at least in terms of direct cost-effectiveness). An installment financing plan arrangement led to an additional 50 000 CFLs sold, but suffered from legal and institutional difficulties. Data on the income levels of consumers purchasing CFLs under the program are not available, so it is difficult to judge how significant the first-cost barrier was among these consumers and how replicable the program would be to a larger class of consumers. It has been suggested that mainly upper-income consumers purchased the bulk of CFLs for cash.

Table 1 CFL program approaches

Program	Subsidized prices	New distributor mechanisms	New consumer financing mechanisms	Consumer education and information	Type of implementing agency	Lamp distribution mechanism	Lamp supply mechanism
Brazil give-away	X	X		X	Utility	Direct install	Bulk procurement
Brazil subsidy	X		X	X	Utility	Retail stores	Ordinary wholesale
Denmark	X	X	X	X	Utility	Retail, contractors, utility offices	Ordinary wholesale; bulk procurement
Jamaica	X		X	X	Utility	Utility offices	Bulk procurement
Mexico	X		X	X	Utility	Utility offices	Bulk procurement
Peru			X	X	Government agency	Retail stores	Ordinary wholesale to retailers
Poland	X	X		X	International consulting firm (utility affiliate)	Retail lighting stores	Supplier-provided subsidies; bulk sales and performance agreements
Thailand		X		X	Utility	Convenience stores (7–11)	Bulk procurement
UK subsidy	X	X			Utility/agency with government support	Retail lighting stores, supermarkets, utility offices	Supplier-provided subsidies; wholesale; and bulk procurement
UK give-away	X	X		X	Semi-governmental agency	Direct install and give-away	Bulk procurement

In Thailand, lamp distribution through the chain of '7–11' convenience stores and price reductions solely through bulk purchases appears to be working well. This approach has made CFLs more accessible to a larger base of consumers, although this approach can also create market distortions at the distribution level by discouraging competition. With bulk purchases but no subsidies, the retail prices of CFLs (estimated at US$9) are about 40% lower than normal retail prices. In 1996–1997, the program sold 230 000 CFLs, but recent economic difficulties in Thailand will undoubtedly increase the first-cost barrier among a larger segment of consumers and reduce program delivery.

Where utilities provided subsidies, the retail price reduction has typically been 40–50% in the programs examined (although in the Mexico and Brazil cases there were reductions of up to 60% or 70%). This is consistent with experience with rebate programs in the United States, which have proven effective at promoting basic lighting improvements with rebates from 20% to 50% of the product price (Nadel, 1992). In some cases the retail price reduction was partly attributed to large economies from bulk lamp purchases by a program, especially in very immature markets. For example, in Mexico consumers received a very favorable retail price estimated at about US$5–US$8 (compared with a market price of up to US$25 or more) due to a utility subsidy (estimated at about US$7–US$10 per lamp) and economies from bulk purchases by the utility. The Mexican utility sold 1.7 million CFLs with no difficulty. In Jamaica, an estimated subsidy of US$6 per lamp, combined with bulk purchases by the utility led to an estimated retail price of around US$6 per lamp (price data are sketchy).

In the Brazil subsidy program, the retail price reduction was entirely due to subsidies. The utility CPFL ran three parallel programs in three cities where the intention was to isolate the effect of the rebate level. Thus, the same type of marketing and information strategies were employed in each city. A 30% rebate generated sales of 5700 lamps within the pilot period of a month, while 60% and 70% rebate levels sold the full quota of 10 000 lamps per city well before the pilot period had ended. The success of the high rebate indicates that first-cost is an important barrier. This is also underlined by the fact that the most popular lamp was the cheapest lamp, a circular electromagnetic lamp which sold for US$16 without rebates.

The Poland subsidy program was unique in the way subsidies were channeled through the private-sector. The intention was to use manufacturers' knowledge of the marketplace to maximize CFL sales per dollar of available subsidy. In this case, a large retail price reduction (about US$6) was possible with a smaller program subsidy (about US$2) because of manufacturer subsidy contributions and the multiplier effects of VAT tax and retail markups. During 1995–1997 in two separate promotions, consumers bought 1.2 million CFLs through the project (half within the first month of each promotion), with over 40 different models represented. This program was easy to manage, was considered cost efficient, and allowed use of available distribution channels. Five manufacturers participated in the subsidy program, although two manufacturers (General Electric and Philips Lighting) dominated the program. Both were seriously pursuing the Polish market and Phillips was the most aggressive player in the Polish market before the project began. Further, at every step of the project, an open and competitive process was used and the GEF executing agency (IFC) went to considerable lengths to avoid any conflicts of interest in administering the program.

A mechanism similar to Poland was first used in the UK subsidy case, where 3 million CFLs were sold from 1994 to 1997. A rebate of about US$1.60 offered by the Energy Savings Trust (EST) was matched by a similar amount by the lighting industry. The industry had to bid in order to qualify for the rebate. The combined EST contribution and the manufacturer contribution (about US$3) translated into a significant reduction in retail price. In the earlier programs the average reduction was about US$8 (from a US$24 retail price). Because of increased competition and lower prices, the retail price reduction in 1997 was about US$5 (from a US$16 retail price). EST estimates the program administration costs at 10–15% of their total funding.

In Jamaica, a CFL sales program by the utility began slowly with mail solicitation only, but participation greatly accelerated once a direct-contact strategy, in which applicants could interact with customer service office staff, was tried. Half of the consumers paid for the energy efficiency measures with credit provided by the utility, suggesting the high-first-cost barrier is significant.

In the Brazil give-away program, the utility CEMIG estimates a total cost per lamp, including installation, of US$8. In the UK give-away program, the program cost per lamp was an estimated US$11. The give-away, direct installation approach appears very effective if a utility needs to fix acute distribution capacity shortages.

Another successful approach was a voluntary agreement by manufacturers to produce more efficient lighting products in the Thailand program. Such an agreement was instrumental in transforming the entire Thai market for T-12 lamps into a market where only the more efficient T-8 lamps are sold. This market is estimated at 45 million lamps per year. Under the voluntary agreement, all manufacturers and importers of T-12 lamps agreed to produce or import T-8 lamps exclusively. In return, the Thai electric utility (EGAT) engaged in an extensive public education and information campaign during 1993–1995. EGAT also conducted testing to ensure uniform performance of the new T-8 lamps. By 1995, all lamp manufacturers and importers had complied with the agreement, and almost all T-12 lamps had been eliminated from the market. Success was aided by a zero net cost to manufacturers (reduced T-8 production costs paid for the production conversion), and T-8 retail prices similar to those for the T-12 lamps. Success was also attributed to cultural factors; the utility stated that the public considered such voluntary agreements more desirable and fairer than price incentives like rebates or subsidies.

Other program approaches, such as research and development, equipment standards, industry quality management programs, product labeling and standardization regulations, were not apparent in the non-OECD cases. The Danish case suggests that in mature CFL markets in OECD countries, these approaches are more significant in overcoming the quality, compatibility, and consumer preference barriers, which become more important as information, first-cost, and credit barriers diminish in significance. Danish utilities have acknowledged the role of early CFL rebate programs in developing the CFL market in Denmark. But as CFLs got cheaper the relative effect of utility rebate programs decreased. Moreover, high volumes of imports of low-quality CFLs created a backlash on the Danish market. The problem grew worse as more and more makes and types entered the market and consumers had an increasingly hard time choosing what product to buy (Kjaerulf, 1997). Since 1994, Danish CFL programs have moved away from rebate programs towards an increasing focus on quality, testing and labeling. Danish utilities contracted with the Danish Illuminating Engineering Society to manage a test program by an independent accredited testing laboratory to test CFLs according to the IEC standard testing protocol (Pedersen, 1997). Later, the so-called *ignition tests* also became part of the standard tests. Lamps that have passed the CFL tests are placed on a utility-supported quality CFL list, the *Sparepaere®* list. The utilities also promote a *Sparepaere®* label with the text 'recommended by your utility.' In 1997, the Swedish Energy Administration also joined the testing program, which has reduced the cost burden of the CFL quality program on Danish utilities. The *Sparepaere®* list is increasingly being acknowledged as a proof of quality outside Denmark as well – European-wide press releases announced that Lumin8, an Irish newcomer to the CFL market, had passed the Danish test (Lumin8, 1997).

The educational and marketing effectiveness of these programs is more difficult to assess, and evaluations are generally limited to anecdotes. For example, in Poland survey results indicated that a majority of consumers felt that special labeling for environmentally-friendly products was of 'great or decisive importance' in their decision-making (NECEL, 1997a). The school education program was commended by the Polish Ministry of National Education, which wrote a letter to the project management in June 1997 saying 'it is apparent that as a result of the project large numbers of students and teachers have gained a useful insight into the use of energy and its impact on the environment.' In the view of project management, the public education component was most successful with print media and educational efforts involving NGOs and local governments.

Technology diffusion and market transformation impacts

The program approaches discussed above all appear effective in distributing a targeted number of CFLs and in creating greater awareness, but differ in their technology diffusion and market transformation impacts. Project impacts on markets are both direct and indirect. Direct impacts occur during the projects themselves as a result of specific interventions like marketing campaigns, subsidized sales, new capabilities, new pilot credit mechanisms, etc. But these interventions must then 'ripple out' in space, time, or among firms and individuals to affect the market in a geographically broader, longer-term, and/or more institutionally diverse manner (Martinot, 1998).

Measuring changes in markets is not simple because markets are complex phenomena, but these impacts could be classified as:

- changes in market sales and structure;
- changes in product prices and costs;
- changes in the characteristics of products and services;
- aggregate markets move along a theoretical S-shaped technology-diffusion curve;
- particular consumer groups or classes progress through known diffusion stages (knowledge, persuasion, decision, implementation, evaluation);
- changes in communication networks among market participants;
- organizational transformations of market participants;
- changes in macro-economic and regulatory frameworks.

Unfortunately, few cases yet provide good information about the technology diffusion and market transformation impacts of programs. The Poland case provides the best data so far on the potential market transformation effects from a CFL program because of extensive pre-project and post-project market research that has been carried out in conjunction with the project. For example, retail prices of CFLs are lower by approximately 30% in real terms after the project. A global manufacturer of CFLs and foreign companies from Germany, China, and Japan have all entered the Polish market. The project led to a large change in consumer awareness about CFLs and the number of households with CFLs increased from 11.5% to 19.6% of all households. The percentage of retailers stocking CFLs climbed from 70.5% to 74.6% of retail lighting stores. A sustainable market is also aided by word-of-mouth from those with positive experiences; in one survey, 97% of consumers said they were 'satisfied' or 'very satisfied' with the CFLs, while in another, 43% said CFLs performed better than expected-and only 3% said worse (NECEL, 1997a; EEI, 1997). One set of obstacles to market transformation in a situation like Poland is that high inflation, electricity tariff increases, and quarterly or semiannual utility billing can obscure the bill savings from CFLs because the amounts of utility bills from one bill to the next keep changing. This will tend to diminish the verification of savings by the public over the longer term.

Extensive surveys done for the UK programs, especially the low-income-household give-away programs, provide detailed information on indirect benefits. Market research has shown that give-away programs in the UK have influenced poor households to buy additional CFLs, which were becoming cheaper and more available on the UK market. Free-driver analyses showed that the give-away programs generated an additional 3.5% in indirect lamp sales after the 1994 program, an additional 6.5% as a result of the 1995 program, and up to 20% more after the most recent 1996–1997 program. All total, the give-away program gave rise to an indirect benefit of an additional 10% of direct sales.

Studies of the UK rebate programs also estimate indirect benefits at about 10% of the total program sales of 3 million CFLs (an additional 300 000 indirect CFLs). At the same time, the rebate programs estimated free-riders (those who would have purchased lamps anyway, in the absence of the program) at about 10% also, thus essentially canceling out the indirect benefits. Nevertheless, higher indirect benefits are suggested by recent research on the European domestic lighting sector, which indicates that households that have been persuaded to buy one CFL tend to buy additional ones if they are easily available on the market (University of Oxford, 1998). And other indicators show market impact from both the UK programs is significant. In 1993, less than 10% of households had at least one CFL installed. By 1997 this figure had gone up to 23%. More households also had more than one CFL installed. The awareness of CFLs has gone up from approximately 50% in 1993 to more than 75% in 1997. Average UK CFL prices have dropped from about US$24 in 1993 to about US$16 in 1997.

The Thailand T-12–T-8 conversion also provides a successful example of market transformation, in which virtually the entire market in Thailand switched to a more efficient product in a relatively short time period. This case shows that successful voluntary negotiations and agreements with manufacturers and importers can be conducted on a comprehensive market-wide basis in a short period of time, provided that suppliers are few in number and the utility has a good relationship with the private sector.

In Peru, the CFL program led to a high degree of consumer awareness about CFLs (75%), and two-thirds of consumers surveyed after the program intended to buy CFLs. From a cumulative sales of 100 000 CFLs total nationwide before the program, unconfirmed annual sales projections after the program were 250 000. Several new manufacturers have entered the market, including some lower-quality brands. Concerns existed that the poorer quality would undermine the program's effectiveness, but these concerns proved unfounded, according to one analyst, perhaps because a powerful consumer-protection agency was established. It is interesting to note that CFL prices, already high at US$20 (including high import duties) before the program, increased during the program. No data are available on the long term effects on prices and markets.

In the Brazil cases, the utility CPFL has not tried to estimate indirect program deliveries, but it is probably fair to say that the many small Brazilian pilot programs taken together have helped to raise awareness of CFLs. Geller *et al* (1997) identify the activities of Brazil's utilities as one of the driving factors in the strong and ongoing growth of the market for efficient lighting technologies that has taken place in Brazil during the 1990s. But in an immature market like Brazil, a give-away approach appears to do less for market evolution than in more mature markets.

In the case of a utility-implemented program like Mexico, continued replication of the program depends upon continued utility implementation and financing, although when program participants were asked in a survey if they would buy CFLs in the future at market prices, only 30% answered no. Market transformation effects are difficult to assess in the Mexico case because of the lack of established baselines and surveys of non-participants. The CFLs installed under the program are likely to have a demonstration effect, but this may be insufficient to catalyze a broader market. Although there are no data available on the current private-sector CFL market and distribution networks in Mexico, the utility-distribution mechanism may tend to have a dampening effect on market development at the retail level. It appears that wealthy consumers are leaders in technology adoption, due to ability to pay, knowledge, and/or higher electricity rates. Surveys of program participants have shown that 50% already knew about CFLs before the program, both through seeing them in supermarkets and hearing about them through friends. From 9 to 19% of participants had already purchased CFLs before participating in the program. No survey data are available of non-participants to see how overall public awareness has changed.

Like Mexico, the Thailand CFL program is being implemented by a utility, but distribution is occurring through a convenience-store distribution network. The Thailand program is thus creating new private-sector distribution networks that presumably can lead to lasting market transformation once the utility program is finished. The Thailand program also differs from Mexico in that subsidies are not provided, so the functions of bulk purchasing and marketing could more readily be taken over by private-sector entities once the utility program is completed.

The failure rate of lamps from programs has an important influence on market transformation effects. Consumers paying a premium for high-efficiency lighting do not expect reduced reliability with increased cost. In the Thailand T-12 replacement program, breakage rates for T-8 lamps from thinner-tube construction appeared higher, from anecdotal evidence, which may lead to reduced consumer acceptance of the new T-8 tubes. Failure rates varied substantially across the programs studied – from a high of about 10% in Jamaica to about 2% in Mexico. In the UK give-away program, the failure rate went from 7% in the 1994/95 program to only 2% by 1997. These failure rates compare with 1–2% in OECD countries. Poor power-quality can be a factor in higher failure rates. The lesson here is that lighting technology designs should be suited for the power quality environment in which they will be applied, in order to minimize failure rates and increase consumer acceptance of the new technology.

In the UK give-away programs, retention of the lamps was quite high. An average of 86% of those who had received a free CFL in the six months prior to the survey were using it. Where CFLs had been installed by the program staff, 92% were still using it, whereas where the consumer had installed it, 81% of the CFLs were in use. Data on retention rates in other programs are not available.

Besides the indirect market impacts of the programs discussed above, there are also additional follow-on activities initiated by these programs which deserve note. Of course the sustainability of utility rebate programs depends upon continued utility financing, but such financing appears likely in several cases. In Mexico, the utility has gained extensive experience in implementing CFL projects, and has considered the project successful. With the revenue from the sales of CFLs already purchased under the program and with additional contributions, CFE was reportedly planning to purchase an additional 900 000 lamps, which would bring the project total to 2.5 million. It is also planning a nationwide CFL project to sell consumers four million CFLs by 2000 using the Ilumex model. In Poland, there are plans for a new program to push purchases of hard-wired luminaires by housing cooperatives, and a new 'Green Lights' program is beginning with demonstration lighting replacements in a few schools. In the UK, the success of the low-income programs convinced the UK government in 1997 to make free CFLs a permanent part of its Home Energy Efficiency Scheme.

Cost-effectiveness of GHG reductions and economic analysis

We calculated rough estimates of cost effectiveness from a greenhouse-gas (GHG) mitigation perspective and also from consumer and social economic perspectives. There are many uncertainties and disputes about the cost and energy savings data for these programs, so we present here only the broader, more robust results from our calculations (for notes on these calculations, see the appendix). Direct cost effectiveness is based upon program costs and the direct program installations of CFLs. Indirect cost effectiveness includes further installations of CFLs based upon estimates of the indirect market transformation effects as noted below. Direct cost-effectiveness of the CFL programs studied appears to vary from a low in the US\$5 to US\$10/ton CO_2 range (Poland, Thailand, Denmark, UK subsidy programs) to a high in the US\$25 to US\$40/ton CO_2 range (Mexico, Jamaica, Peru, Brazil low-subsidy, and UK give-away programs), depending upon project factors and assumptions. Higher costs per ton of CO_2 abated (up to US\$60/ton CO_2) occurred in the high-subsidy and give-away programs in Brazil that were small-scale pilots.

From our analysis of the cases, we find the following factors tend to make programs more cost-effective:

- no or low per-lamp subsidies;
- leveraging of private-sector contributions and retail tax/markup multiplier effects;
- high marketing and distribution cost-effectiveness.

Conversely, the following factors tend to make programs less cost effective:

- high per-lamp subsidies;
- low wattage of existing incandescent lamps;
- natural-gas-fired electricity generation relative to coal or fuel oil;
- high program overhead (non-subsidy) costs per lamp, especially for small numbers of lamps;
- program objectives not strictly focused on energy efficiency.

Aside from the direct cost-effectiveness numbers cited above for subsidy approaches, the indirect cost-effectiveness of market transformation approaches appears to be below US\$5/ton CO_2. A prime example is the Thailand T-12–T-8 replacement program, in which production for the entire country was converted from T-12 to T-8 lamps, saving 10% of electricity consumption from these lamps with an estimated cost-effectiveness of less than US\$1/ton CO_2. Based upon an indirect program delivery over five years for the Poland program equal to the direct program delivery, an additional 1.6 million lamps would be purchased in the next five years as a result of the project. This would mean the combined (direct plus indirect) program cost-effectiveness would be doubled, to US\$3 or US\$4/ton CO_2.

Economic returns to consumers from CFLs appeared to be in the US\$5 to US\$15 per lamp range (NPV at 18% discount rate), although these depend heavily upon the choice of discount rate and assumptions, made in lieu of actual data, about the number of hours per day that lamps are used. Denmark is a special case, with an estimated US\$30 per lamp consumer NPV because of very high electricity rates and taxes paid by consumers. The UK give-away program is another special case, with an even higher consumer NPV due to the combination of free lamps, high electricity rates, high lamp usage, and high wattages of bulbs being replaced. Social economic benefits from energy savings are in the US\$5–US\$10 per lamp range (NPV at 10% discount rate), exclusive of electric power capacity cost savings but including program costs. Brazil exhibits larger social economic benefits, in the US$10–US$20 per lamp range, due to high marginal electricity production costs. The UK cases also exhibit larger social economic benefits, due to low program costs per lamp and high electricity production costs. Economic benefits from electric power capacity savings are uncertain because of uncertainties in lighting coincidence factors, long-run marginal capacity costs, and load growth and future capacity expansion plans, and have not been calculated for the case studies examined because of a lack of consistent data. In one case, surveys showed a peak load coincidence factor of 0.5 rather than the 0.8 originally estimated during program design, probably reducing the expected capacity benefits.

In the Mexico case, cost effectiveness and economic benefits both appear to be lower than originally forecast because the fuel mix for electricity generation has changed (partly to gas), and because average lamp usage per day (3.2 h) is less than originally estimated (4 h). In addition, a large share of the consumers who purchased CFLs through the project had relatively high monthly electricity consumption. Consumers with high monthly consumption pay electricity rates higher than the utility's marginal generation costs, thus lowering the economic benefits to the utility due to lost profits from these consumers. Conversely, lamps installed by low-consumption consumers with electricity rates lower than marginal generation costs reduced the utility's subsidy payments.

In the Brazil subsidy cases, program costs exclusive of rebate costs were very high (estimated at US$7 per lamp) because of the small size of the programs (26 800 lamps had to carry all administrative and marketing costs). Including rebate costs, program costs per lamp were about US$20. The program cost per lamp is almost equal in the 30% and 60% rebate programs, due to the fact that only half as many lamps were sold in the 30% program, but program non-subsidy costs were a constant per program. This suggests that for new CFL programs, rebates must be high enough to make the fixed investments in marketing and information cost-effective. The experience also suggests that rebate programs can be expensive to run if not carefully designed and sufficiently large-scale.

In cases where existing incandescent lamps are low wattage, CFL replacement will result in increased lighting services and reduced levels of energy and economic savings. Increased lighting services is a legitimate program goal, but the total consumer benefits in this case must also account for increased lighting services in addition to economic returns. For example, in Jamaica a survey of 40 homes which had been provided with CFLs found that approximately 40% of the incandescent lamps in use prior to CFL replacement were 40 W or less, suggesting that CFL replacement is resulting in increased lighting services and lower levels of energy and economic savings than might otherwise be expected. Similar effects were observed in Brazil's give-away programs, but with one significant difference. Existing incandescent lamps were high-wattage (estimated at 60 W), but were consuming much less energy than their rating (and providing much less light) because of almost permanent voltage drops during peak hours. When large numbers of lamps were replaced with CFLs, the electric system performance improved and lighting levels also improved. In addition, the utility gained by avoiding expensive system upgrades, and other consumer appliances could function properly (Jannuzzi, 1998). (In contrast, in the Brazil subsidy case, the utility CPFL gathered good data on replaced lamp wattages using consumer surveys in all three cities. In the 30% subsidy program, 24 W CFLs replaced incandescent bulbs averaging 79 W.)

Peak-load reduction benefits are also significant for utilities. In the Brazil give-away case, the utility CEMIG measured a total peak-load reduction of 1.8 MW from almost 90 000 CFLs. The peak-shaving DSM pilot program in Poland was successful in demonstrating peak load reduction in electric power distribution systems and avoided or delayed utility capital costs. About 7500 CFLs were installed in one capacity-constrained neighborhood, which meant an average of about five CFLs per household in that neighborhood. Peak power levels at some monitoring points declined by about 15% (Granda, 1997). In the Peru case, the Ministry in charge of the program regarded it as successful in meeting its peak load reduction objectives: by 1995, Lima's peak load dropped by 93 MW as a consequence of all the measures in the energy-saving campaign, with the CFLs accounting for about a fifth of the peak load reduction, approximately 20 MW. In Thailand, the utility EGAT estimated a 240 MW load reduction from the T-8 market transformation program.

Other program implementation lessons from Europe and the United States

Early CFL programs in Europe and the United States focused on the economic benefits of CFLs. In retrospect the emphasis on economic benefits was too strong, especially because of the quality, compatibility, and consumer acceptance issues mentioned previously. Many of the earlier experiences from European and North American utilities and energy agencies are now being taken into account when new programs are designed. These experiences are relevant for developing countries. Examples include:

- High first cost has been identified as a major barrier even in affluent European countries.
- High first cost in combination with uncertainty of CFL performance (i.e. lifetime) erode confidence and willingness to invest in CFLs. Quality management programs such as in Denmark have helped.

- Daily operating hours per CFL tend to be lower in households with high numbers of luminaires. A household in Northern Europe or in the United States will often have more than 30 luminaires, and consumers may not install lamps in high-usage locations. Gains from each CFL will tend to be higher in homes with fewer lamps. For example, in the UK low-income-household programs, operating hours tended to be longer because of the relatively small number of luminaires per household.
- Higher-wattage CFLs are needed than suggested by nominal lumen specifications. Lumen output is measured in perfect laboratory conditions, but because of high ambient temperatures, poor optical performance, unfavorable lamp orientation and other factors, a CFL will typically give less light than expected. European researchers have recommended that 13-W and even 15-W CFLs be used in performance and economic comparisons with standard 60-W incandescent lamps, rather than 11-W models.
- European and US program designers are increasingly focusing on the non-energy benefits of CFLs, such as reductions in fire hazard and discomfort from excessive heat generation.
- Many programs are increasingly supporting dedicated CFL luminaires to avoid 'snap-back' — the future replacement of program CFLs with incandescent lamps.

Conclusions

Our review finds that there is a large body of existing lighting-program experience from which to design further cost-effective lighting programs. This experience comes not just from OECD countries but from non-OECD countries as well. The eight country cases chosen for the study are part of a much larger existing literature. All of the lighting programs studied were adequately designed to meet their immediate objectives and had delivered or were soon to deliver the target quantities of high-efficiency lamps to consumers, often ahead of schedule. The Poland, Thailand, and Danish cases in particular show that CFL and other lighting programs can clearly be cost-effective if properly conceived and designed. The review suggests that cost-effectiveness is primarily a function of good project design and external conditions, and that implementation does little to alter the fundamental cost-effectiveness of different program approaches. The potential indirect impacts on national lighting markets and long-term GHG reductions through the market transformation aspects of the lighting programs are also very significant. For many cases these indirect impacts are difficult to assess because of the absence of pre-project baselines. In the Poland case, substantial post-project market transformation information is already available. For all projects, full market transformation effects can only be properly assessed if indirect impacts are monitored at a point some years past project completion.

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Appendix: Notes for cost-effectiveness and economic analysis

The results of the cost-effectiveness and economic analysis are based on the following assumptions and notes: (1) The results presented are intended as rough estimates only, for looking at broad patterns across multiple programs. (2) Reasonable assumptions were made for data that was unavailable. (3) A consumer discount rate of 18% and a social discount rate of 10% is assumed for all cases. (4) The costs of (baseline) incandescent lamps are ignored in NPV calculations. (5) NPV calculations are based solely on avoided energy costs and not avoided capacity costs because of the difficulties of obtaining comparable data across all cases. (6) Utility NPV is not calculated because some programs are not utility programs and this measure would not be a common basis for comparison. (7) CO_2 emissions factors used are 0.95 ton CO_2/kWh for coal, 0.75 for oil, and 0.55 for gas, plus an assumed 10% for transmission and distribution losses. These factors produce different results in a few cases from the CO_2 estimates in other published material, due to differing methodologies, assumptions, and/or interpretation of time frames and annual vs total emissions in published numbers. (8) For cost effectiveness of the Thailand T-8 fluorescent lamp program, five years' worth of indirect effects were assumed for the total market of 45 million lamps per year. (9) Indirect benefits for Poland are based upon assuming a without-project market growth rate of 20% from 1997 to 2003, and an increase in that rate to 30% due to the project. (10) The Brazil give-away program is not very cost-effective from a CO_2 abatement point-of-view, but the purpose of the program was to both save electricity *and* to increase the service level offered to customers. The previously installed incandescent load caused frequent voltage drops during peak hours, and the lamps were not running according to their nominal power. Thus although the average load reduction is low, operating hours are estimated to have doubled, and lighting levels are substantially higher.