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The effect of efficient lighting on the environment: pilot project in Palestine

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Abstract In this paper, we present the results and experience gained through the Energy Conservation Pilot Project in the Town of Salfeet/Palestine. Also, we describe five case studies of energy-efficient programs in five countries—Mexico, China, Philippines, Poland and Vietnam. The project was funded by the UNDP/GEF and executed within the framework of the cooperation between An-Najah National University, the UNDP/GEF, and Salfeet Municipality. The project aims mainly to draw the public attention towards the importance of energy conservation in reducing pollution as well as running cost. In fact, a major component of the project was the replacement of the incandescent lamps for about 40% of the residents of Salfeet (626 families), the 40–100 W lamps were replaced by 18 W compact florescent lamps (CFL). Each benefited family was given three to five CFL free of charge depending on number of persons per family. It is found that the total energy saved because of lamp-replacement in Salfeet is about 5,000 kWh/month, and the total emission saved of CO_2 is about 5,792 kg as coal is burnt to generate electricity. Furthermore, the project has improved public awareness about energy conservation concepts and their positive impact on local and global climate changes.

Introduction

The Town of Salfeet is located in the middle of the West Bank, Palestine, at about 24 km south of Nablus. Salfeet has a population of about 9,000 inhabitants representing 1,444 households. The electrification of Salfeet began in 1960. Currently, 100% of the homes are connected to the electrical network. The community of Salfeet represents the Palestinian community to a large extent; that is why Salfeet was chosen to be the area of implementation of Energy Conservation Pilot Project in Palestine.

In simple words, energy conservation means efficient (less) consumption of electricity, which means, in terms of energy conversion, less fuel burning at the generation stations, and hence less emission of harmful gases such as CO_2 and SO_2. In fact, less fuel burning reduces greenhouse effect and acid rain, which obviously has a positive impact on the local and global environment (Turner 1993).

The process by which energy-efficient lighting reduces pollution is simple. The authors found, through field measures, that lighting accounts for about 25–30% of household expenditure of electricity in Salfeet (which can be considered as an average in Palestine). Salfeet, as well as other Palestinian cities, buys its electricity from the Israeli Electricity Company (IEC), which burns coal to generate electricity. Burning of coal often results in various types of pollution, including acid mine drainage, toxic waste and air pollutants. The compact fluorescent lamps (CFL) is one well-known product that consumes only 20% electricity for the same light output as given out by the incandescent lamp and which, if adopted in a big way, has the potential of reducing peak electric power loads very significantly (Kumar et al. 2003). According to the EPA, it is estimated that every kilowatt-hour of electricity avoided prevents the generation of 1.2 kg of carbon dioxide, 10 g of sulfur dioxide, and 4 g of nitrogen oxides. Each of these pollutants causes environmental damage: Carbon dioxide (CO_2) causes global warming, sulfur dioxide (SO_2) causes acid rain, and nitrogen oxides (NO) cause both acid rain and smog. Moreover, burning less fuel reduces other types of pollution resulting from mining and transporting power plant fuels and disposing of power plant wastes. Further more, electricity generation produces toxic

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trace metals, including beryllium, cadmium, and chromium, copper, manganese, mercury, nickel, and silver (EPA 1993).

Case studies worldwide

Many efficient lighting programs have been conducted worldwide. Many of these programs have been called market transformation programs. These programs attempt to change the fundamental structure of the lighting marketplace in many countries (Geller and Nadel 1994). In this section, five case studies of energy-efficient lighting programs will be discussed.

Case study 1: Mexico high-efficiency project

The global environment facility (GEF 1994) has funded the Mexico high-efficiency project. The main goal of the project is to reduce greenhouse gas emissions as well as local environmental contamination through the replacement of incandescent lamps with fluorescent light lamps in two major Mexican markets: Nuevo Leon and Jalisco. These two cities in Mexico, are the largest that the Federal Electricity Commission (national electric utility) serves. The primary lighting lamps in Mexico in end use of electricity homes are incandescent. The project increased institutional capacity for technological change and energy conservation, and strengthen the Federal Electricity Commission and its capacity to practice demand side management on a sustainable basis. The Federal Electricity Commission purchased the CFL and distributed them to the households of customers. The Federal Electricity Commission purchased the lamps at a very competitive price from the manufacturers. The savings on the cost of the lamps were passed on to the end user, the customers. The low cost of the CFL and the utility subsidy helped the low-income consumers to benefit from this program.

Direct cost per ton of carbon dioxide avoided of the CFL programs studied is about \$25/ton CO_2. The two factors that tend to make the Mexico program less cost-effective are: high per lamp subsidies and natural-gas-fired electricity generation relative to coal or fuel oil.

Although there is no data available on the current private sector CFL market and distribution networks in Mexico, the program tend to have a dampening effect on market development at the retail level, and continued replication of the program depends upon continued utility implementation capacity and financing. When program participants were asked in a survey if they would buy CFLs in the future at market prices, 30% answered no. No surveys have been conducted of non-participants to see how public awareness has changed. Failure rates of the lamps in the Mexico programs is about 2%. Poor power quality can be a factor in higher failure rates (GEF 1994; Friedmann et al 1995 ; Sathaye et al. 1994).

Case Study 2: China barrier removal for efficient lighting products and systems

The Global Environmental Facility (GEF 2004) has funded the China barrier removal for efficient lighting products and systems project. The project aims at addressing identified market barriers to widespread use of energy-efficient lighting in China by broadening the China green lights start-up efforts. The objective of the project is to save energy and protect the environment by reducing lighting energy use in China in 2010 by 10% relative to a constant efficiency scenario. The specific objectives include upgrading of Chinese lighting products; increased consumer awareness of, and comfort with, efficient lighting products and the establishment of a vibrant, self-sustaining market in efficient lighting products and services. In China, it was identified that there was a national savings potential of 40% by shifting to lamps with performance characteristics typical of current western practice—but without changing the market share of various lamp types—and of 60% by adopting the best commercially available lamps (Fu Min et al. 1997).

Case Study 3: Philippines efficient lighting market transformation project

The Philippine efficient lighting market transformation project is intended to address the barriers to widespread utilization of energy efficient lighting (EEL) systems in the Philippines. It is aimed at contributing to the realization of the country's sustainable development objectives and its goal in reducing GHG emissions in the energy sector. It will specifically focus on the promotion of an energy-efficient version of linear fluorescent lamps (i.e., slim tube T8 triphosphor), CFLs, high- intensity discharge lamps, ballasts (low-loss electromagnetic and electronic), and luminaries. The project will accelerate integration of EEL promotion programs in the energy conservation and energy efficiency programs of the Philippines' Department of Energy, enhance private sector's involvement and appreciation of the benefits of EELs, and ensure that environmental impacts associated with the widespread use of EELs are mitigated. The objective of the project is to remove remaining technical and market barriers to the accelerated introduction and large-scale promotion of energy-efficient fluorescent lighting systems in the Philippines. The goals of the projects are achieved by: (1) conducting a preliminary characterization of the Philippine markets for energy-efficient lighting; (2) characterizing the stage of development in the legal, regulatory and fiscal frameworks setup by the GOP to promote energy end-use efficiency (including that of lighting); (3) holding consultations with key government and private sector stakeholders in the promotion of energy-efficient lighting technology markets to identify the technical and market obstacles keeping them from attaining their goals in advancing

more efficient lighting technologies; and (4) proposing activities to help overcome those identified obstacles. As many of the electric distribution utilities are already committed to sponsor, yet ill prepared to field, lighting-focused DSM programs, the PDF will focus heavily on overcoming the technical, financial and marketing capability barriers imposed by their small size (GEF 2004).

Case study 4: Poland efficient lighting project (PELP)

Direct subsidies have been competitively awarded to domestic manufacturers of qualified CFL to reduce wholesale prices to dealers and retail prices to consumers. Manufacturers and wholesalers will be required to pass on full savings on to retailers, who will apply a standard percentage-based mark-up, passing savings on to consumers. The retail price reduction of ($6) was possible with a smaller subsidy ($2) because of manufacturer contributions and the multiplier effects of VAT tax and retail markups (essentially contributions by the government and retailers). This has sparked demand for CFLs in Poland, demonstrating the financial and commercial benefits of energy-efficient lighting and resulting in large power savings and reduced emissions from coal-fired generation plants. A pilot peak load shaving Demand Side Management Program was conducted by municipal government and local utilities in three towns. Compact fluorescent discounted lamps were sold to households in areas where peak electric load was constrained (Martinot and Borg 1998). This case in particular shows that CFL and other lighting programs can clearly be cost-effective if properly conceived and designed. Direct cost per ton of carbon dioxide avoided by the CFL programs is in the range of $5–$10/ton CO_2.

This case provides the best data so far on the potential market transformation effects from a CFL program because extensive pre-project and post-project market research 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 significant change in consumer awareness about CFLs, and the number of households using 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 (GEF 1995).

Case study 5: Vietnam energy efficiency public lighting (VEEPL) project

Vietnam energy efficiency public lighting project is aimed at building both technical and policy support for transition to more energy-efficient public lighting in Vietnam. By increasing the energy efficiency of public lighting installed over the next 10 years, the project will significantly reduce electricity consumption by the public lighting sector in Vietnam compared to what it otherwise would have been. Reducing electricity consumption will reduce emissions from the Vietnamese electricity generation sector. Although VEEPL specifically targets public lighting (street lighting, public spaces and public buildings), the technical capacity and policies established through the project will support lighting efficiency efforts in other sectors as well. In order to remove barriers to the energy efficiency of public lighting, VEEPL is organized in five components: (1) policy development; (2) technical support; (3) financing; (4) technology demonstration; (5) information dissemination and awareness rising (GEF 2004).

Methodology

In this paper, we present the results and experience gained through the Energy Conservation Pilot Project in the Town of Salfeet. The total budget of the project (under agreement No. cc10-10-99) was $400,000. The general goal of the project was to draw the public attention towards the importance of energy conservation in reducing pollution as well as running cost. Indeed, the following objectives were achieved through workshops, brochures, and TV ads:

1. Increase public awareness about climate changes and their relation with the efficient use of energy.
2. Encourage people to use solar energy and train them how to improve the efficiency of their solar collectors.
3. Improve the awareness and capacity of engineers and technicians in areas related to energy conservation.
4. Introduce the public to applicable measures, recommendations and techniques that mainly lead to residential energy conservation.

The different phases of the energy conservation pilot project in Salfeet

The project was started in April 2000 and completed in September 2001. The project was divided into the following phases:

Field survey and measures (phase one)

According to the records of Salfeet municipality, the distribution of electricity consumers among the different sectors is as presented in Table 1 below:

Table 1 shows that the residential sector represents 87% of the total consumers. This fact oriented us to concentrate on the residential sector. Therefore, the objectives of the field survey, which we conducted in the town of Salfeet as phase one of the project were:

Table 1 Distribution of consumers among different sectors

Sector	No. of connections	% out of total
Industrial	32	2
Commercial	180	11
Residential	1,444	87

1. To determine type, number, average age, and average consumption of the electrical appliances used in the households of Salfeet.
2. To determine the percentage of households using solar collectors, average age of solar collectors being used, and their preventive maintenance.
3. To determine the average number of persons per family and average income.
4. To evaluate the public degree of awareness about energy conservation concepts.

In conducting the field survey, representative sample of 155 households was randomly selected. The size of the sample is about 11% of the residential consumers in Salfeet. A proper questionnaire oriented for the residential sector was first prepared. A working team of 20 students (males and females all from Industrial Engineering Department) was formed to perform the survey. It took the team two working days to complete the survey. In addition to pocket money, the students gained good technical and social experience through their participation.

The collected data were analyzed using the SPSS software, the main findings can be summarized as follows:

1 The average number of incandescent (average 60 W) lamps is 6.5 lamps per household.
2 The average operating hours per day equals 3 h for each incandescent lamp. Therefore, the average consumption of incandescent lamps per month per family is found to be 35 h/month.
3 Almost all the families did not have any idea about what are called low-consumption lamps, and indicated that they had never used it in their homes before.
4 The average number of refrigerators (and freezers) was found to be 1.25 with an average daily consumption of 3–4 kWh. The average age of the refrigerators is 8 years, most of them were second hand.
5 The average number of washing machines was found to be 1.05 per family. The average power of the washing machine is 2.5 kW, and the average operating hours per week is 6 h.
6 The average family consumption for other different activities is about 1,500 W per day.
7 Ninety-one percent of the families are using open system water-heating solar collectors (not photovoltaic) with an average age of 16.7 years. Only 21% of the families maintain their collectors well.
8 Almost all the families were not aware of energy conservation concepts and its effect on the local and global environment.
9 The average income of each household is about $450 per month. The average cost of the kWh is about 0.15 $ in Salfeet, which means that the average saving per family per month is about 1.15 $. This amount of saving makes 0.25% of the family average income per month.

Based on the above findings, the authors decided that the community of Salfeet is in need of properly designed public awareness campaigns about energy conservation; this was phase two of the project.

Public awareness campaigns (phase two)

Different awareness campaigns were carefully designed and implemented. The awareness campaigns were in the form of workshops, brochures, advertisement in local newspapers, interview on local TV, and TV programs.

The participation of the beneficiary community was notable. For example, Women's organizations, Chamber of Commerce and the Municipality in Salfeet had participated in attending and conducting workshops. In fact, without the participation of these organizations it would be very difficult to achieve the goals and objectives of the project.

The following is a sample of different activities related to the public awareness campaigns:

1 Conducted workshops:
   - A workshop titled "Introducing the People of Salfeet to the Plan of the Energy Efficiency Project".
   - A workshop titled "Positive Measures and recommendations on Energy Conservation in the Residential Sector and its effect on the Environment".
   - A workshop titled "Introducing Electrical Technicians to the most Efficient Installation and lighting Techniques".
   - A workshop titled "Promoting Companies and Industries towards Positive Measures Related to Energy Conservation in Industrial Sector".
2 Preparing several promotional brochures regarding "Conserving Lighting Consumption" and "Benefits of Solar Water Heaters in Palestine".
3 Publishing advertisement in the three local newspapers about energy conservation in general and lighting system in specific and the positive effect on the environment.
4 Conducting 36 min interview on local TV explaining the benefits of energy conservation on the economy and the environment.
5 Conducting special program on energy conservation at local TV station and broadcasting it more than once.

6 More than 2,750 CFL were distributed for free to the beneficiaries in Salfeet to replace incandescent lamps.

Lamp-replacement program (phase three)

Initially, the purpose of the project was to replace and install incandescent lamps with high-efficiency compact fluorescent as a revolving funds project. As a result of the survey that the researchers conducted in the town of implementation project, it was concluded that each household will purchase three to six CFL and the cost of these lamps ($8/lamp) will be paid on six installments. Each payment will be approximately the amount of money that is saved as a result of installing high-efficiency lamps. Also, the participants of this program were given a grace period of one billing cycle before the municipality starts collecting the cost of the lamps. The collected money will then be used to install more CFL to the rest of the population in the town. But, as a result of the economical and political situation in Palestine, the research funder (UNDP) agreed to give away the lamps free of charge to 626 families. The municipality administered the distribution and installation of the lamps.

Analysis and results (phase four)

The authors of this paper introduced the idea of residential energy conservation as a pilot project to a Palestinian small town, Salfeet. It was explained to the beneficiaries of the project (through workshops, newspaper ads, brochures and special TV programs) that the effect of energy conservation would be reflected as low electrical bills in terms of kWh and total money paid. In addition, it would have a positive effect on the environment.

The effect of energy conservation promotion was felt positively on the paid electrical bills. The people who participated in the project have a monthly saving as a result of the energy saving. Also, there was a positive effect of reducing the emission as a result of burning less fuel. The strategy that was followed in this project through the workshops and the awareness program is that the energy conservation is a gainful practice for the person and the society as a whole. The women's organization of Salfeet had a very good influence in following good practices for their families. Also, in the workshops that were conducted in Salfeet, most of the participants were women, which is a good indication that women had a very active role in the success of the project and in the success of the awareness program.

The project had showed clearly a capacity building for both the direct beneficiaries and indirect beneficiaries. For example, the electrical technicians in Salfeet were trained on the latest energy conservation measures and techniques especially in the installation of lighting. We believe that the technicians are now well-trained on the benefits of good installation in terms of energy conservation and electricity losses. Also, the participants (both in the workshops and in the lamp replacement program) are benefiting greatly from the tips and advice regarding the energy conservation and its effect both on the money saving and its effect on the environment.

As a result of the replacement program, 2,753 CFL (18 W) were distributed to 626 families in Salfeet. The total energy saved by these families, based on the analysis of the electricity bills, is about 5,000 kWh/month. The energy savings are summarized in Table 2 as follows:

In fact, there are many factors influencing the final actual savings:

1. Number of hours that the lamps are on differs from house to house. It was assumed (based on the survey) that the number of hours the lamps were on was 3 h.
2. New electrical equipment might be introduced during the study period.
3. Number of family members might be different since the survey and the purchasing of lamps.
4. New visitors to the household and the behavior of these members.
5. If the occupants were on summer vacation or not.

By taking the average family savings per month as 7.71 kWh, we can calculate the pollution savings of CO_2 as follows:

Pollution savings of CO_2 = 7.71 kWh/family * 626 families *1.2 kg/kWh = 5,792 kg

Table 3 below summarized all the pollutants savings as a result of lamp replacement and the public awareness campaigns.

Table 2 Summary of energy savings

Saving per month	KWh
Minimum saving per family	4.8
Maximum saving per family	30
Average saving per family	7.71
Average saving per lamp	4.8

Table 3 Summary of pollutants savings as a result of lamp replacement

Pollutant	Amount	Unit	Pollutant	Total
CO_2	1.20	kg/kWh	CO_2	5,792 kg
NOx	4.00	g/kWh	NOx	19,306 g
SO_2	10.00	g/kWh	SO_2	48,265 g
Beryllium	0.02	mg/kWh	Beryllium	97 mg
Cadmium	0.05	mg/kWh	Cadmium	241 mg
Chromium	1.30	mg/kWh	Chromium	6,274 mg
Copper	0.59	mg/kWh	Copper	2,848 mg
Manganese	2.27	mg/kWh	Manganese	10,956 mg
Mercury	0.04	mg/kWh	Mercury	193 mg
Nickel	1.18	mg/kWh	Nickel	5,695 mg
Silver	0.25	mg/kWh	Silver	1,207 mg

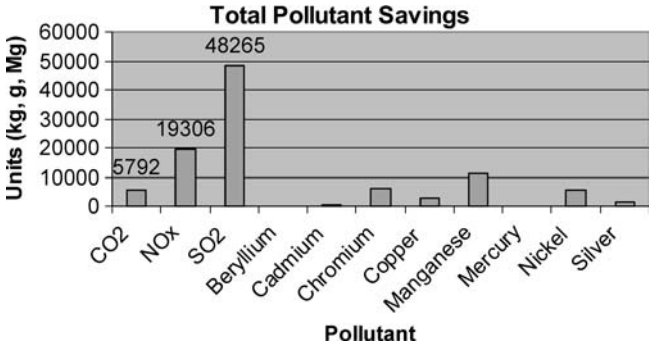

Fig. 1 Total pollutant savings as a result of lamp replacements (note CO_2 in kg, NOx in grams, SO_2 in grams and the rest are in mg)

On the other hand, Fig. 1 below shows the total pollution savings as a result of lamp replacement and the public awareness campaigns.

Conclusions and recommendations

As a conclusion, the project had satisfied the many positive points. It is found that the total energy saved because of lamp-replacement in Salfeet is about 5,000 kWh/month, and the total emission saved of CO_2 is about as much as 5,792 kg of coal is burnt to generate electricity. Furthermore, the project has improved public awareness about energy conservation concepts and their positive impact on local and global climate changes. Also, people of Salfeet improved their knowledge about types of efficient lamps. Finally, as a direct result of this project the capacity of technicians in areas related to installation of lighting and energy efficiency has been improved and strengthened . In fact, the results of the project can be more effective and sustainable if the Municipality of Salfeet monitors the installed CFL and encourages other families to install such lamps.

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