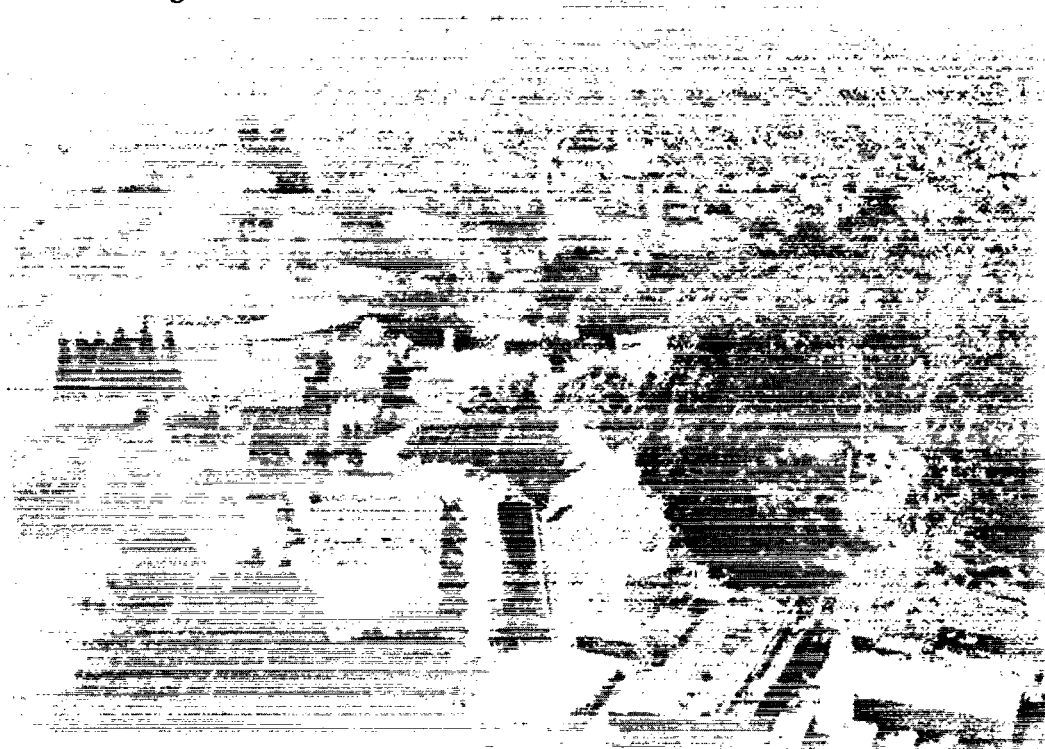# ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Electricity Savings Potentials in the Residential Sector of Bahrain

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Energy and Environment Division

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Electricity Savings Potentials in the Residential Sector of Bahrain

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Electricity is the major fuel (over 99%) used in the residential, commercial, and industrial sectors in Bahrain. In 1992, the total annual electricity consumption in Bahrain was 3.45 terawatt-hours (TWh), of which 1.95 TWh (56%) was used in the residential sector, 0.89 TWh (26%) in the commercial sector, and 0.59 TWh (17%) in the industrial sector. Agricultural energy consumption was 0.02 TWh (less than 1%) of the total energy use.

In Bahrain, most residences are air conditioned with window units. The air-conditioning electricity use is at least 50% of total annual residential use. The contribution of residential AC to the peak power consumption is even more significant, approaching 80% of residential peak power demand. Air-conditioning electricity use in the commercial sector is also significant, about 45% of the annual use and over 60% of peak power demand.

This paper presents a cost/benefit analysis of energy-efficient technologies in the residential sector. Technologies studied include: energy-efficient air conditioners, insulating houses, improved infiltration, increasing thermostat settings, efficient refrigerators and freezers, efficient water heaters, efficient clothes washers, and compact fluorescent lights. We conservatively estimate a 32% savings in residential electricity use at an average cost of about 4 fils per kWh. (The subsidized cost of residential electricity is about 12 fils per kWh. 1000 fils = 1 Bahrain Dinar = US$ 2.67.) We also discuss major policy options needed for implementation of energy-efficiency technologies.

INTRODUCTION

Electricity is the major fuel (over 99%) used in the residential, commercial, and industrial sectors in Bahrain (Morsy and Al-Baharna, 1995; Bahrain Ministry of Electricity and Water, 1993 and 1994). The installed capacity, electricity demand, and annual electricity use in Bahrain have grown substantially since 1971. From 1971 to 1986 the installed capacity increased from 75 MW to 988 MW; the capacity has stayed fairly constant since 1986 (See Figure 1). The power demand, however, has kept increasing and it is rapidly approaching the maximum generation capacity. The Department of Electricity and Water, hence, is faced with the problem of either installing new capacity or initiating energy efficiency programs to curb the demand.

According to 1992 census data, of the total annual electricity consumption of 3.45 terawatt-hours (TWh), 1.95 TWh (56%) was used in residential sector, 0.89 TWh (26%) in commercial sector, and 0.59 TWh (17%) in industrial sector. The agricultural energy consumption was 0.02 TWh (less than 1%) of the total energy use.

The average electricity use during months of January, February, March, and April was 88.5 million kilowatt-hours (MkWh). Assuming that this 88.5 MkWh is used for non-air-conditioning (AC) use and that the monthly non-air-conditioning electricity use remains the same throughout the year, the annual non-AC consumption in the residential sector will add up to 1.06 TWh, leaving 0.89 TWh for air-conditioning use. This AC electricity use, hence, accounts for over 45% of annual residential consumption.

The contribution of residential AC to the peak power consumption is even more significant. Most AC electricity is used in the four months of July, August, September, and October.[1] For these four months, the average residential consumption is 254 MkWh of which 88.5 MkWh is non-AC and 165.5 MkWh (65%) is for AC use. Morsy and Al-Baharna (1995) estimate that on the hourly level, the share of AC use to hourly demand can approach 80%.[2] Since the structure of the current electricity prices in Bahrain does not include any peak demand component, we will use the monthly data to perform cost/benefit analyses of the proposed energy-efficiency programs.

This paper will focus on outlining options for energy efficiency in electric appliances, mainly for the residential sector. In future efforts, we plan to expand this study to include commercial sector.

Figure 1. *Electricity Demand and Use in the State of Bahrain*
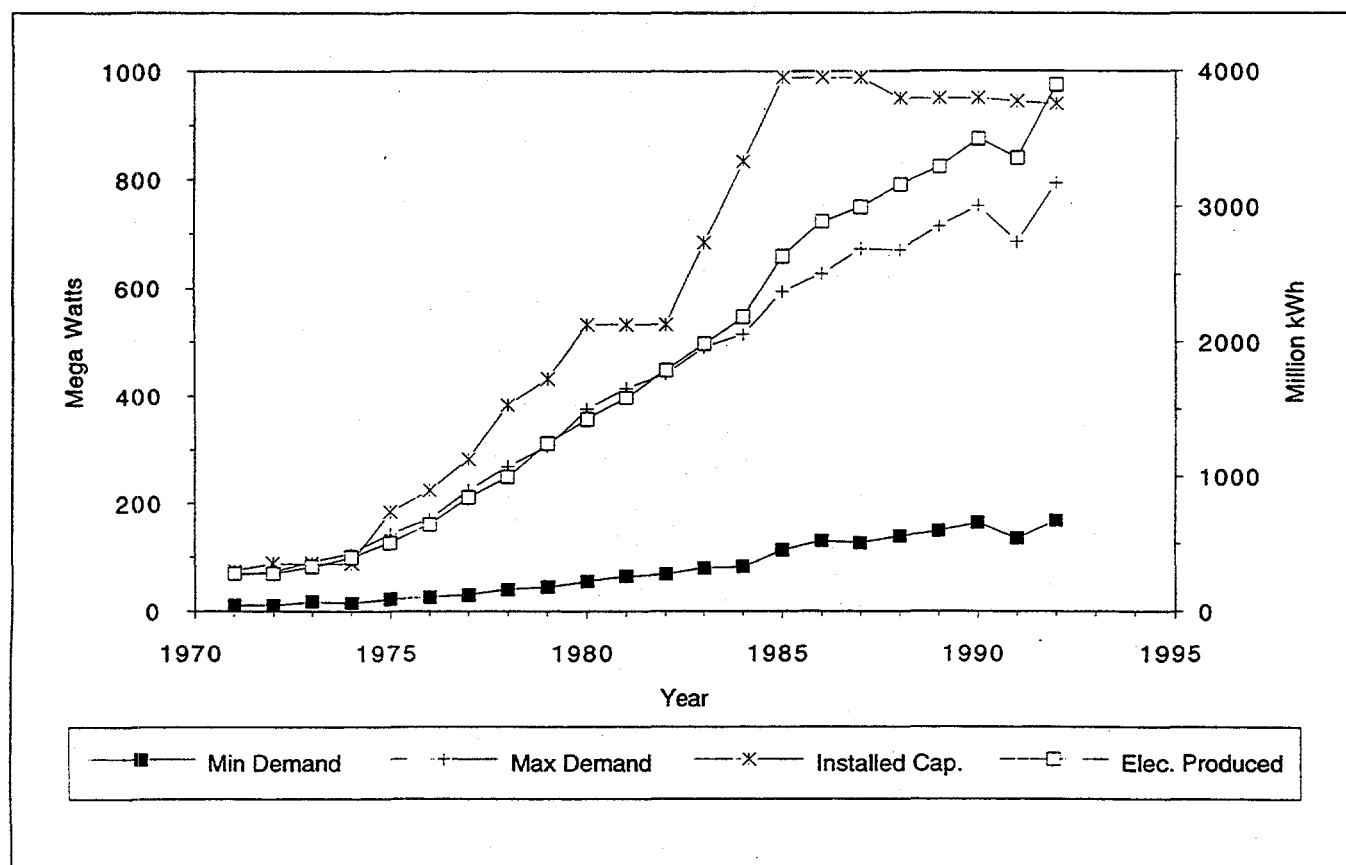
Source: Bahrain Ministry of Power and Water (1993, 1994).

ELECTRICITY COST

The Ministry of Electricity and Water provides the data in Table 1 for the cost of electricity generation. Gas is the major fuel for electricity generation (Bahrain Ministry of Water and Power 1993, 1994). (Currency is Bahraini Dinar, BD; BD1 = 1000 fils = US$ 2.67).

CONSTRUCTION OF A BASE CASE

Of the total 83,500 residences in Bahrain, over 79,500 are flats, villas, or conventional and traditional houses (see Table 2).

Table 1. *Electricity Cost (fils/kWh)*

	1993	1994
1. Generation cost w/o depreciation	7.3	7.5
2. Generation cost with depreciation	14.2	15.0
3. Average sales price	10.5	11.3

Table 2. *Housing Stock in Bahrain (1991 Census)*

Housing Type	Number of Units	Percent of Stock
Flat	22,867	27.4
Villa	11,602	13.9
Conventional	29,347	35.2
Traditional	15,699	18.8
Others	3,955	4.7
TOTAL	83,470	100.0

Morsy and Al-Baharna (1995) have gathered detailed building characteristic data for about 500 buildings in Bahrain, focusing primarily on the residential sector. Flats are small attached single-story residences with about 87m² to 107m² floor area. Conventional and traditional houses are single-

or double-story detached residences with floor area ranging from 90m^2 to 140m^2. Villas are larger single- or double-story single-family residences with floor areas ranging from 300m^2 to 500m^2. Based on the collected data and using DOE-2 computer program, Morsy and Al-Baharna have developed nine prototypes of residential buildings and simulated their heating and cooling energy use.

This analysis is based on the data provided by Morsy and Al-Baharna. They assumed that the entire building is air conditioned, however, most buildings are only partially conditioned. To simplify our analysis of energy efficiency measures, we have (1) estimated an average electricity use by end use for the entire residential sector and (2) conservatively assumed that only 50% of the simulated air-conditioning energy savings for each energy efficiency measure is feasible. The basecase energy use for other household appliances is also based on Morsy's data.

Table 3 provides estimates of air-conditioning use and cost for an average house. From Table 3 two conclusions can be made: (1) AC is the major appliance contributing significantly to annual electricity use and peak summer demand, and (2) the contribution of other appliances to annual electricity use in the residential sector is as significant as AC. From these observations, we will recommend that any energy-efficiency program targeting residential sector

should address both AC and non-AC components of the energy use.

Table 3 indicates that the average residence is using about 11,200 kWh for cooling. However, as Table 4 shows, the total electricity consumption for non-AC per residence is about 10,100 kWh per year. That would leave a total of 3,200 kWh per year unaccounted for. Morsy (1995) makes the observation that the winter baseload will not be applicable to the summer base load because of the following reasons:

● the space heating load should be subtracted from the summer base load

● the water heaters for most houses are not turned on during the hot months of the year.

Hence, if we account for these changes in the seasonal operation, the cooling portion of the annual energy use will significantly increase. Hence, we add the unaccounted portion of the average residence, the 3,200 kWh annual consumption, to the cooling energy use. This would modify the cooling energy use to 14,400 kWh per year, which constitutes about 59% of annual cooling load.

We have also constructed base cases for average winter and summer months. Based on the assumptions that the water heater is on for seven months of the year and heating is required for four months of the year, we have calculated the annual electricity consumption as summarized in Table 4. The state-wide contribution of residential space cooling is

Table 3. Electricity Use per Household

Parameter	Average for 79,500 Residences
1. Average electricity use per house (kWh/yr)	24,500
2. Average AC use per house (kWh/yr)	11,200
3. Annual electricity cost (BD/yr)	277
4. Annual AC cost (BD/yr)	127
5. Typical winter consumption (kWh/mo)	1,100
6. Typical winter bill (BD/mo)	12.4
7. Typical summer consumption (kWh/mo)	3,190
8. Typical summer bill (BD/mo)	36.0

Table 4. Basecase Electricity Consumption

End Use	Winter (kWh/mo)	Summer (kWh/mo)	Annual (kWh/yr)
1. Water heater	425	0	3,000
2. Lighting	125	125	1,500
3. Space heating	145	0	600
4. Refrigerator	125	125	1,500
5. Washer	80	80	1,000
6. Others	210	210	2,500
7. Space cooling	0	2,660	14,400
TOTAL	1,100	3,200	24,500

estimated at 14,400 x 79,500 = 1,145 MkWh per year (59%). Hence all other non-space cooling end uses add up to about 803 MkWh per year.

ELECTRICITY CONSERVATION POTENTIAL IN RESIDENTIAL SECTOR

The cost of conserved electricity (CCE) is calculated by

$$CCE\left[\frac{BD}{kWh}\right] = \frac{\text{Annualized investment [BD / yr]}}{\text{Annual electricity saved [kWh]}}$$

Annualized investment = Total investment

$$\times \frac{d}{1 - (1+d)^{-n}}$$

where d is the discount rate and n is the lifetime of the efficiency measure in years. In our cost benefit analysis we assume a real discount rate of 7%.

Space cooling

Morsy and Al-Baharna (1995) have performed extensive computer simulations to analyze electricity use in the Bahrain residential sector. They have identified that improving building insulation, reducing infiltration rate, using double-glazed reflective windows, and increasing thermostat cooling setpoint from 22.2°C to 25.6°C can lead to a potential reduction of 67% in AC electricity use. In their calculations, they assumed all residences are fully air conditioned. Although a fully air-conditioned house would provide a broader comfort to the residents, currently, most houses are not fully conditioned. In calculating the cost effectiveness of energy-efficiency measures (EEMs), we conservatively reduce the Morsy's simulated percentage savings by half.[3] Implementation of these EEMs in non-conditioning zones will provide additional comfort although they will not save electricity. Thus, these measures should be targeted to air-conditioned homes. Supporting calculations for these energy efficiency measures are summarized in Table 5.

Reducing infiltration. Reducing infiltration from one air change per hour (ACH) to 0.5 ACH will save about 5% of AC use (average simulated savings is 10%). Sources of infiltration are leaks in the frame around the AC units, windows, and doors. We estimate a cost of about BD2 to fix these leaks and reduce infiltration by 50%. The life of the measure is assumed to be 15 years.

Increasing thermostat setpoint. Increasing thermostat setpoint from 22.2°C to 25.6°C saves 8% (average simulated savings is 16%). This measure costs nothing to implement.

Insulating roofs and walls. Insulating the building roofs and walls with 5 cm (2 inches) of polystyrene sheets reduces energy use by 19% (average simulated savings is 38%). The cost of this measure is about BD300 per residence. The life of the measure is estimated at 30 years.

High-efficiency air-conditioning unit. he current stock of the AC units is very inefficient; most units have a power rating of 1300 to 1700 W/ton. This corresponds to a coefficient of performance (COP) of approximately 2.1 to 2.7, including both evaporator and condenser fans. We assume that the average air conditioner in Bahrain has a COP of 2.2. Energy-efficient units in the market have a COP rating of at least 2.5 (a 14% improvement) and they cost approximately BD25 more per unit. Assuming the average residence has three window units, this would translate to an additional cost of about BD75 per residence. The window AC units are expected to last for 15 years.

Double-glazed windows with reflective films. The fraction of window area in most houses is less than 10% (Morsy and Al-Baharna 1995). Only new and large houses have large window areas. Simulations show that as much as 19% of the air-conditioning in large houses can be saved by using double-glazed windows with reflective films. In this analysis for an average house we assume that there is about 25m² of window area and that it would cost approximately BD15 per square meter to replace them with the double-glazed windows. Hence the total cost is about BD375 per house. The estimated average electricity savings is about 9.0%. The new windows should last for 30 years.

Conservation supply curve for space cooling. The above calculations are based on the annual cooling electricity consumption of 14,400 kWh per residence. As we apply conservation measures in the order of the least expensive to the most expensive, the base energy use for the incremental measure decreases. Table 6 shows estimates of energy-savings potentials as measures are added, assuming a geometric savings for series measures applied to the same end use.

Other residential appliances

In this section, we provide preliminary estimates for the impact of energy-efficiency measures in reducing electricity use in refrigerators, freezers, washer and dryers, water heating, and lighting in the residential sector. The results of these calculations are also summarized in Table 5.

Refrigerators and freezers. We assume that each house has at least one refrigerator and the average electricity consumption is 1500 kWh per unit per year. These inefficient units can be substituted gradually with efficient units that use about 850 kWh per year; a saving of 650 kWh per year. We estimate that the efficient units will have an incremental

Table 5. Estimates of Cost of Conserved Electricity and Total Savings

End Use/Measure	Energy Saved per House[+] (kWh/yr)	Annualized Cost of Measure (BD/yr)	Cost of Conserved Electricity (fils/kWh)	Total Electricity Saved (MkWh)
Space Cooling				
Reducing infiltration	720	0.2	0.3	57.2
Increasing thermostat setpoint	1,152	0.0	0.0	91.6
Insulating roofs and walls	2,736	21	7.7	217.5
High-efficiency airconditioning units	2,016	7.5	3.7	160.3
Using double-glazed windows with reflective films	1,296	25.3	20.3	103.0
Refrigerators and Freezers	650	2.4	3.7	51.7
Washers	300	1.5	5.0	19.0
Water Heating	1,050	1.0	1.0	58.4
Lighting	750	2.1	2.8	59.6
Space Heating[‡]				

[+]The saving estimates are for space cooling measures taken as 50% of savings simulated by Morsy and Al-Baharna (1995).
[‡]Adding insulation to the roofs and walls and reducing infiltration will also reduce the demand for space heating. In this paper, we are not addressing electricity savings of the space heating.

Table 6. Conservation Supply Curve for Residential Space Cooling

Measure	Base CCE (fils/kWh)	Base Savings (MkWh)	Adj. CCE (fils/kWh)	Adj. Savings (MkWh)
Thermostat setpoint	0.0	91.6	0.0	91.6
Reduced inflit	0.3	57.2	0.3	52.6
High Eff. AC	3.7	160.3	4.2	140.1
Insulation	7.7	217.5	10.2	163.5
Window treatment	20.3	103.0	33.3	62.7
TOTAL				510.5 (44.5%)

cost of approximately BD30. The lifetime of a refrigerator is typically 15 to 20 years; in these calculations, we assume a lifetime of 20 years. The natural market turnover is then 5% to 7% per year. Some utilities in the United States increase the penetration rate of the efficient refrigerators by designing and implementing programs to swap old inefficient refrigerators with the new efficient units.

Washer and dryers. For this calculations, we use data from United States (Turiel et al. 1995). A typical inefficient washer and dryer in the U.S. use about 1500 kWh per year, of which approximately 50% is for washing and 50% for drying. In Bahrain most houses do not have dryers, however, utilization of washers per household is more than in the U.S., because of the higher number of occupants. Hence, we estimate that an average house uses about 1000 kWh per year for clothes washing. The efficient clothes washer uses about 30% less electricity. The incremental cost of the efficient washer is about BD15. Washers last for about 12 to 15 years; in these calculations, we assume a lifetime of 15 years. We also assume that only 80% of houses have washers.

Water heating. The energy used for water heating is a function of the amount of hot water use in the residence, which in turn is a function of the number of occupants in the house, the number of showers taken in a day, the usage of hot water in appliances such as clothes washers and dishwashers. In addition, a significant fraction of electricity use in water heaters with tanks is wasted as stand-by heat loss. Measures applicable to electric water heaters include: changing the unit to gas water heater (a 70% efficiency improvement in source energy; we do not use this measure in this calculations), changing the storage tank unit to terminal water heaters, insulating the water heater tank, lowering the thermostat setting of the water heater and hence reducing the stand-by heat loss, and finally reducing consumption by using low-flow shower heads. Inefficient water heaters in the U.S. use about 4000 kWh per year. The typical number of occupants in a U.S. residence is about 3 to 4 people. So the average energy use per occupant is about 1000 kWh per person. In Bahrain, the average number of household occupants is about 6 to 8. Assuming the same usage pattern as the U.S., a typical residence in Bahrain with an inefficient water heater uses about 6000kWh to 8000kWh per year. However, water heaters are not generally used during the hot months of the year. For these calculations, we arbitrarily assume that an average house in Bahrain uses about 3000kWh per year.

The efficient units in the U.S. use about 1200 kWh to 1800 kWh per year, a 55% to 70% improvement in energy efficiency. We conservatively assume that in Bahrain we can initially obtain a 35% improvement in electricity efficiency. The cost for this improvement is estimated at about BD10.

A water heater lasts about 10 to 15 years; in these calculations, we assume a lifetime of 15 years. We also assume only 70% of the houses have electric water heaters.

Lighting. An average house in Bahrain probably uses about 1500 kWh per year on lighting. Using compact fluorescent lights to substitute for the lights that are heavily used in a house will save about 50% of lighting electricity use (Note that CFLs use about 70% less electricity than incandescent lights.) CFLs last about 10,000 hours, about 10 to 15 times longer than incandescent bulbs. On an annualized cost basis, a CFL may cost less than the total cost of all the incandescent bulbs that it is replacing. For these calculations, we estimate an incremental cost of about BD4 per CFL and four CFLs per house, or BD16 per house. The life of the CFL is assumed to be about 10 years.

Space heating. Adding insulation to the roofs and walls and reducing infiltration will also reduce the demand for space heating. In this paper, we are not addressing electricity savings for the space heating.

Conservation supply curve for non-space-conditioning. Table 7 summarizes the energy efficiency potential in non-air-conditioning end uses. Note that unlike measures targeted at the air conditioning, these measures apply to different end uses and adjustments to the base energy use are not necessary. The reduction of electricity use in the conditioned space reduces the cooling load on the AC units. In these calculations, we have not accounted for this additional savings in electricity use.

Grand Conservation Supply Curve for Residential Sector

Table 8 is the summary of all energy efficiency measures analyzed above. These measures are listed in the order of ascending CCE.

ENERGY EFFICIENCY POLICIES AND IMPLEMENTATION NEEDS

The above calculations show that we can conservatively save about 32% of residential electricity use at an average cost of 4.4 fils per kWh. These energy savings are only possible if (1) the current barriers to energy efficiency in Bahrain are understood and steps are taken to overcome the identified barriers and (2) energy-efficiency programs are given the same level of institutional and financial support as given to electricity generation.

The barriers that are immediately identified in Bahrain include:

- lack of information within the building community,

Table 7. *Conservation Supply Curve for End Uses Other Than Space Conditioning*

Measure	Base CCE (fils/kWh)	Base savings (MkWh)	Adj. CCE (fils/kWh)	Adj. savings (MkWh)
Refrigerators	3.7	51.7	3.7	51.7
Washer and dryers	5.0	19.0	5.0	19.0
Water heaters	1.0	58.4	1.0	58.4
Lighting `	2.8	59.6	2.8	59.6
TOTAL				188.7 (23.5%)

Table 8. *Grand Conservation Supply Curve for Residential Sector*

Measure	Base CCE (fils/kWh)	Base savings (MkWh)	Adj. CCE (fils/kWh)	Adj. savings (MkWh)
Thermostat setpoint	0.0	91.6	0.0	91.6
Reduced inflit	0.3	57.2	0.3	52.6
Water heaters	1.0	58.4	1.0	51.4
Lighting	2.8	59.6	2.8	59.6
Refrigerators	3.7	51.7	3.7	51.7
High Eff. AC	3.7	160.3	4.2	140.1
Washer and dryers	5.0	19.0	5.0	19.0
Insulation	7.7	217.5	10.2	163.5
Sub-total with average cost			4.4	629.5 (32.3%)
Window treatment	20.3	103.0	33.3	62.7
TOTAL			7.0	692.2 (35.5%)

- lack of government personnel experienced in energy efficiency programs,

- lack of government infrastructure,

- perceived lack of importance of energy efficiency,

- current trends in building design practices, and

- perceived increased construction costs.

In a detailed report, Levine and Deringer (1987) provide an excellent review of these barriers in the developing countries.

The following is a brief description of policy and implementation programs that can be designed to target and exploit the energy efficiency potentials in residential sector.[4]

Building energy codes, standards, and guidelines for new buildings

Building energy standards can be very effective implementation strategies for electricity conservation in Bahrain. Many countries have adopted commercial and residential building standards that save 20% to 40% of energy use in the building. Janda and Busch (1992) have compiled data on the worldwide status of energy standards in buildings. A partial list of countries that have building standards include most developed countries in North America and western Europe, and developing countries such as Singapore, Thailand, and Kuwait. In addition, the American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has developed several generations of building standards including ASHRAE Standard 90.1, 90.2, and 100 (ASHRAE 1989, ASHRAE 1993, ASHRAE 1995). Based on the compiled information, building energy standards should be developed for Bahrain.

Development of standards should be followed by supporting actions to ensure proper compliance and enforcement of the standards. Enforcement of the building code and standards typically occurs at the local level. Hence, local staff and officials need to be trained for enforcement of the standards. This training can be complemented with development and utilization of PC-based programs to facilitate the task of code enforcement.

Energy audits and retrofits of existing buildings

Existing inefficient buildings contribute significantly to electricity consumption well within the next decade. Hence, a near-term solution to energy efficiency in buildings is developing energy audit and retrofit programs for residential buildings. Audit forms can be used to collect building energy-use data and perform analysis of retrofit programs on a building-by-building basis. A by-product of an audit and retrofit program is improvement of the national electricity use by end use and time of the use. A better understanding of end-use electricity consumption will lead to the design of better energy-efficiency programs.

Appliance energy standards and labeling

All residential appliances need to be rated and labeled so that the customer can make an informed decision when he/she is shopping for a new appliance. An effort should focus on compiling and analyzing the efficiency characteristics of appliances in the market, developing a rating and labeling scheme, and providing incentives for energy-efficient appliances. Government's role in this program is crucial.

Development of a market to retrofit buildings

In order to implement measures related to building envelopes, some incentives are needed to create a market for retrofitting existing buildings with insulation, reducing the infiltration of outside air, and replacing the existing inefficient windows with double-glazed reflective ones.

Integrated demand-side management

Energy efficiency should be given the same institutional support as is given to electricity generation. Investment in energy efficiency is needed to achieve objectives. In developed countries various changes in energy utility regulations and electricity pricing have created an environment in which energy efficiency can be a competitive option to energy generation.

The U.S. Department of Energy (DOE) has developed a comprehensive program for an integrated resource planning (IRP) for energy utility companies. IRP compiles data on various energy-efficiency programs and develops guidelines for utility companies that can be used to investigate the role of demand-side management (DSM) in energy planning. Factors that IRP considers include investment planning, DSM program cost, and externalities to both generation and consumption of electricity. Various criteria are considered, including the Cost of Conserved Energy (CCE), Cost of Avoided Peak Power (CAPP), the life-cycle cost of options, and the rate of return on investment can be mentioned.

To encourage the shifting of power for the peak periods to off-peak period, peak electricity is charged either through demand charges or by time of the use (TOU) rate. TOU and demand charges have created a market to load management technologies such as thermal energy storage (TES) or daylighting. In Bahrain, we anticipate that most of the growth in electricity use will be due to the growth of the commercial sector. In such conditions, IRP would lead to a change in daytime electricity rates, which in turn will encourage load management technologies to compete with peak power generation.

Electricity pricing

Electricity pricing is a major issue for energy use in buildings and industry. Social, political, and economic studies have shown that energy prices that are consistent with long-term energy costs will encourage efficient use of energy. Conversely, subsidizing electricity prices will encourage ineffi-

cient use of electricity that is equivalent to burning money in the generation power plants and ties-up capital by investing in unneeded generation capacity. If the government would like to assist its citizens in their electricity bills, incentives and rebates can be given to the rate-payers and customers in a way that can encourage energy efficiency.

Management support

The success of an energy-efficiency program, both at the national level and the customer level, is directly related to the support provided by top management both in the government and the private sector.

Public awareness campaign

Rate-payers in general are very energy-conscientious. Information packages provided at regular intervals (such as with the monthly utility billing) can provide the rate-payers with information on the impact of energy-efficiency measures on reducing their electricity bill.

Demonstration programs

Demonstration projects are successful ways of convincing rate-payers of the effectiveness of energy-efficient technologies. Demonstrations should focus on technologies and end uses that are relevant to the rate-payers. Technologies to consider should include energy-efficient cooling systems, energy-efficient residential appliances, and lighting.

Electricity Consumption Monitoring Programs

Whole-building and end-use consumption data are needed to develop effective energy-efficiency programs. Without accurate data, there is always the danger of designing an ineffective program and, hence, wasting efforts and resources. Residential monitoring programs should focus on a limited number of buildings representing the spectrum of buildings in Bahrain. Besides air-conditioning, other end uses to be monitored include refrigerators, water heaters, lighting, and clothes washers.

CONCLUSION

Our analysis indicate that we can save about 32% of residential electricity use at an average cost of about 4 fils per kWh. Appropriate residential technologies include: energy-efficient air conditioners, insulating houses, improved infiltration, increasing thermostat settings for space cooling, efficient refrigerators and freezers, efficient water heaters, efficient clothes washers, and compact fluorescent lights. The policy options needed for the implementation of energy-

efficiency technologies include development of building energy codes, standards, and guidelines for new buildings; performing energy audits and retrofits of existing buildings; developing a market to retrofit buildings; initiating an integrated demand-side management at the Ministry of Electricity and Water; designing innovative electricity pricing schemes to encourage efficiency; developing structure to enhance management support for energy efficiency both in the private and public sector; initiating a public awareness campaign in support of energy efficiency; developing demonstration programs to showcase efficient strategies and products; and developing programs to monitor electricity consumption in support of design of DSM programs.

ACKNOWLEDGMENT

ENDNOTES

1. These are the utility billing months. Typically the utility billing periods cover the last 10 to 12 days of the prior month and 18 to 20 days of the current month.

2. Air-conditioning energy use in the commercial sector also constitutes a significant portion of the national electricity use. Average commercial electricity consumption for the months of February, March, and April is 46 MkWh per month. Hence, the annual AC use is conservatively estimated at $890 - 12 \times 46 = 340$ MkWh (38%). This 38% only accounts for seasonal variation in AC use and does not include base AC and ventilation energy use in the cold months of the year. Noting that a significant fraction of the electricity use in the commercial sector is for hotels and offices, and that both hotels and offices use AC throughout the year, we estimate that a total of 45% of commercial electricity use is for AC. This figure is similar to the residential fraction of AC electricity use.

   A lower bound for monthly summertime AC electricity use in commercial sector is estimated at 105 MkWh (August through October average) $- 46 = 59$ MkWh per month (56%). Again, including base AC electricity use, the contribution of AC use in the commercial sector can easily approach 60% of the peak monthly consumption for the sector.

3. For instance, Morsy estimates a 10% savings in AC electricity use because of reduced infiltration; we use 5% savings for our cost/benefit analysis.

4. Although, these calculations are performed for the residential sector, the policy options discussed here will equally apply to the commercial sector.

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