

## ENERGY CONSERVATION PROGRAM IN KUWAIT: A LOCAL PERSPECTIVE

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### ABSTRACT

A salient climatic feature of Kuwait is the hot and long summer period of seven months that extends from April to October with temperatures soaring to over 50°C. Weather is generally dry and diurnal variation in ambient air temperature often exceeds 20°C. Cooling for all type of buildings is, therefore essential. As a result, air-conditioning of buildings is the single largest consumer of electricity and it accounts for nearly 75% of nation's peak power demand and over 50% of annual energy consumption. The Ministry of Energy has to meet the growing demand for electricity by building new power plants that require high investments. This paper highlights the advancement in the Energy Conservation Code of Practice for Kuwait and the efficient use of ventilation and cooling systems to meet the building's cooling load in a conservative manner without energy wastage. The paper, moreover, summarizes proven energy conservation techniques (time of day control of the cooling system) and energy efficient technologies (use of ice storage system) resulted from case studies and research work done at Kuwait Institute for Scientific Research. The savings in energy use and production will reduce the fuel consumption at the power plants and will indeed result in less emission of Carbon Dioxide and better environment.

**Key words:** energy efficiency, air-conditioning, control strategies, thermal storage, greenhouse gas emission.

## 1. INTRODUCTION

### 1.1 Energy and Global Emissions

Energy is essential to the modern societies. The availability of reliable energy sources is the key for maintaining economic growth and living standards. The major energy sources include fossil fuels (petrol, natural gas, and coal), hydropower, and nuclear energy. According to the International Energy Agency (IEA) 1997 annual report, the industrialized countries including North America and Western Europe consumed more than 50% of the energy used in the world as illustrated in Table 1 [1].

Burning of fossil fuels has increased significantly levels of greenhouse gases (GHG). The most important greenhouse gases are water vapor (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and several other gases, such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>) [2].

Total energy-related CO<sub>2</sub> emissions for the world in 2001 are estimated at 23,899 million metric tons. Emissions for the industrialized world (North America, Western Europe, and Industrialized Asia) in 2001 are estimated at 11,634 million metric tons, or about 49 percent of the world total. The remaining 51 percent of 2001 worldwide energy-related CO<sub>2</sub> emissions come from developing countries (9,118 million metric tons) and the former Soviet Union and Eastern Europe (3,148 million metric tons) [2].

### 1.2 Environmental Energy Impact

There are environmental and health impacts associated with the energy consumption. Burning of fossil fuels has increased significantly levels of carbon emissions. The carbon emissions have a major impact on changing the global climate by increasing global temperatures that could affect agricultural production, and sea level heights. Environmental impacts due to the burn of fossil fuels are not limited to areas where energy is produced or used but are rather global. The emissions of GHG are causing severe health problems worldwide.

In December 1997, the Third Conference of the Parties (COP3) to the United Nations Framework Convention on Climate Change was held in Kyoto, Japan. At the Kyoto Protocol, 160 countries reached an agreement, whereby the world's developed countries pledged to collectively reduce their GHG emissions to an average of at least 5.2% below 1990 levels, in the commitment period 2008 to 2012 [3].

Developing countries were granted some extension before the global targets apply to them. Energy demands are soaring in the rapidly growing developing countries. One of the most valuable strategies to reduce GHG emissions is to improve the energy efficiency of facilities and power plants that are either controlled or influenced by local governments.

**Table 1. Energy consumption and carbon emissions by region (EIA, 1997).**

Region	Energy Consumption [Quadrillion Btu]			Carbon Emissions [Million Metric Tons]		
	1990	1997	2010*	1990	1997	2010*
Industrialized Countries	183	204	240	2,850	3,039	3,563
Eastern Europe	76	53	63	1,337	878	1,151
Developing Countries:						
Africa	9	11	16	180	214	292
Asia	51	75	126	1,067	1,522	2,479
Central/South America	14	18	30	174	225	399
Middle East	13	18	26	229	297	552
Total	87	122	198	1,649	2,258	4,930
<b>Total (World)</b>	346	379	500	5,836	6,175	8,146

\*: Projections

To maintain economic growth and reduce the environmental impacts of conventional energy resources, energy conservation and energy efficiency have to be considered. Energy savings due to energy conservation and efficiency can avoid the need to build new and expensive conventional power plants beside the following benefits [2]:

- Increase the economic competitiveness since investment in energy conservation provides a better return than investment in energy supply.
- Stretch the availability of the limited nonrenewable energy resources and gain time for possible development of renewable and reliable energy resources such as solar energy.
- Decrease air and water pollution and thus improve health conditions.
- Can decrease building operational and maintenance costs;
- Reduces GHG emissions and other pollutants associated with the combustion of fossil fuels.

New sets of institutions are making it easier for consumers, business, and governments to take advantage of energy efficiency opportunities. These

include government initiatives to set standards and disseminate information about efficiency. These initiatives, pioneered in industrial countries, are now being extended to developing and transition economies. Thailand introduced a \$189 million demand-side management program in 1993. The program first targeted lighting, which accounts for 20% of Thai electricity consumption. The program persuaded Thai manufacturers of fluorescent lights to switch to a new design that consumed 10% less energy. The program eased consumer acceptance through a combination of advertising and imposition of standards for light quality and durability. Within a year the new lighting commanded 100% of the market. Estimated benefit-cost ratios were 54.6 for consumers and 13.8 for society as a whole, taking account of the program cost [4].

One of the main challenges facing the world is to increase the efficiency of energy production, distribution, and consumption to conserve energy, reduce costs, and environmental impacts. Local governments, therefore, are challenged to acknowledge and address their contributions to the long – term risks posed by climate change, as well as to realize the multiple benefits of cleaner and more efficient energy consumption practices. Local governments can directly influence and control many

activities that generate GHG emissions. If the issue of climate change is to be addressed successfully, then the reduction of GHG emissions must also be addressed at the local level.

One of the most efficient scenarios to reduce the GHG emissions in the developing world is to adopt and implement efficient energy strategies and practices. In this section, the energy use conditions of Kuwait are briefly presented to highlight the potential of energy conservation and efficiency programs for the country.

## 2. KUWAIT'S ENERGY SCENARIO

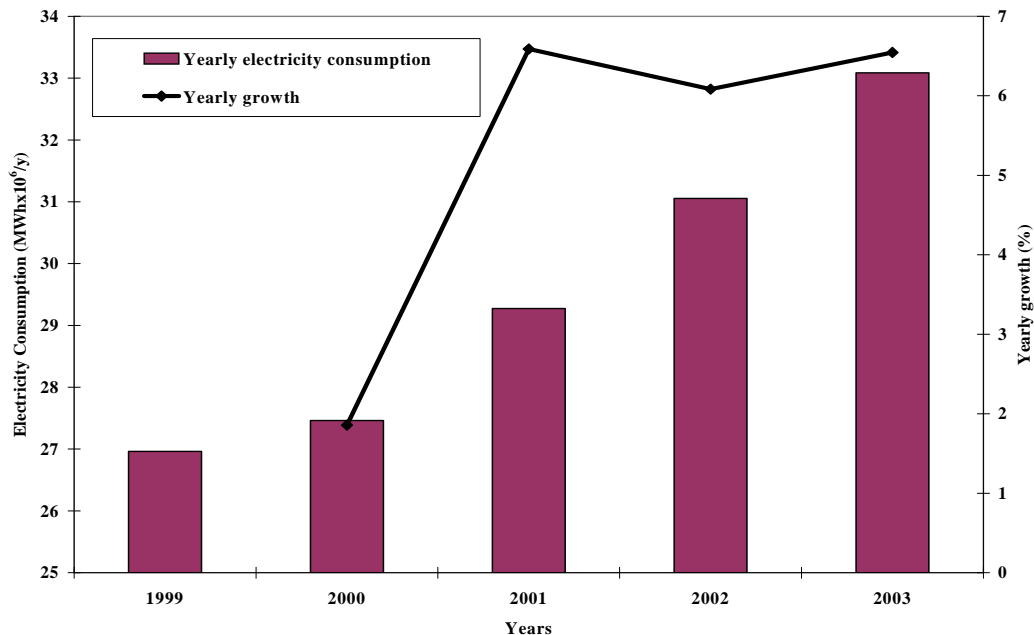
### 2.1 A Local Background

A salient climatic feature of Kuwait and the other countries in the Gulf region is the hot and long summer period of seven months that extends from April to October with temperatures soaring to over 50°C. Weather is generally dry and diurnal variation in ambient air temperature often exceeds 20°C. Cooling for all type of buildings is, therefore essential. As a result, air-conditioning of buildings is the single largest consumer of electricity and it accounts for nearly 75% of nation's peak power demand and over 50% of annual energy consumption. However, the building owners/users are not concerned, as the highly subsidized electricity by the government is available in abundance.

The Ministry of Energy (MOE), the sole supplying agency of electricity in the country, has to meet the growing demand for electricity by building new power plants that require high investments in addition to the recurring expenditure on fuel and the increase in GHG emissions. MOE has been deeply concerned about the yearly growth in electricity demand in Kuwait and has therefore enforced energy conservation measures since 1983 through a code of practice for new and retrofitted buildings.

Electricity worldwide can be generated from either power plants fueled from primary energy sources (coal, natural gas, or fuel oil) or from nuclear power plants or renewable energy sources (such as wind, photovoltaic, and solar thermal sources) [5].

Energy in Kuwait is produced at the power plants that use fossil fuels (oil and natural gas). In Kuwait, the energy consumption has increased in response to the significant demand for electricity due to the urban and economic growth. The demand for electricity is growing at a rate around 6%. For instance, the energy consumption increased from 27.0 million MWh in 1999 to 33.1 million MWh in 2003 (Fig. 1) (MOE, 2003) [6]. Residential buildings are the major consumer and it is responsible for 64% of the total electrical energy consumption (Fig. 2). Kuwait is considered one of the highest per capita consumption of electrical energy in the world [7].



**Figure 1. Annual Electrical Consumption and Growth in Kuwait**

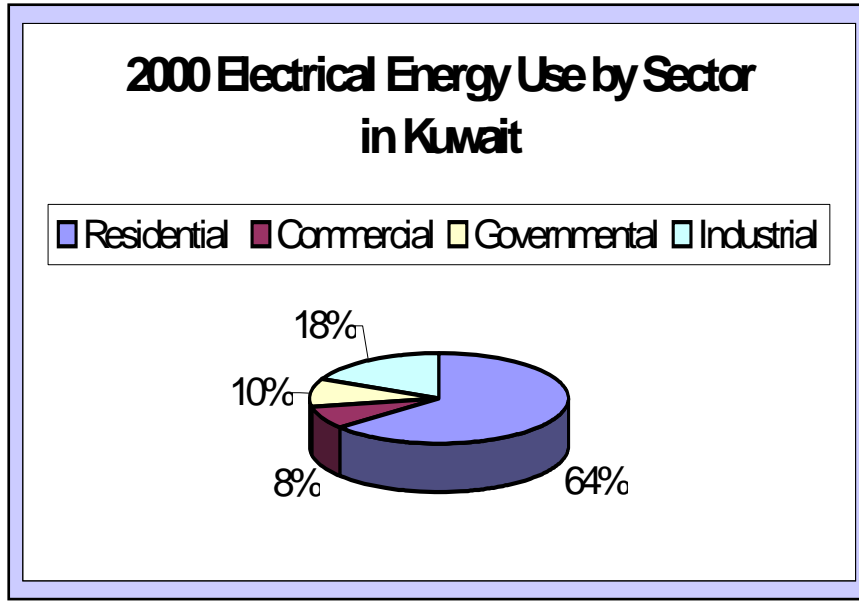


Figure 2. Distribution of Kuwait Electrical Energy Consumption by End-Use Sector.

**2.2 Peak Power Demand**

The monthly electricity consumption in Kuwait for 2003 is illustrated in Fig. 3. The summer power demand for Kuwait is controlled mainly by the demand for air-conditioning as illustrated in Fig. 5 for a peak day. The peak demand of the day occurs at 4:00 PM where the lowest and it follows a typical

pattern as can be noticed in the profile for the peak demand day of the year 2003 value occurs at 7:00 AM. The power demand then rises gradually from 7:00 AM until 4:00 PM and later on falls nearly in the same pattern till 8:00 PM. The profile then has a minor fluctuation till 1:00 AM and then it falls gradually until 7:00 AM.

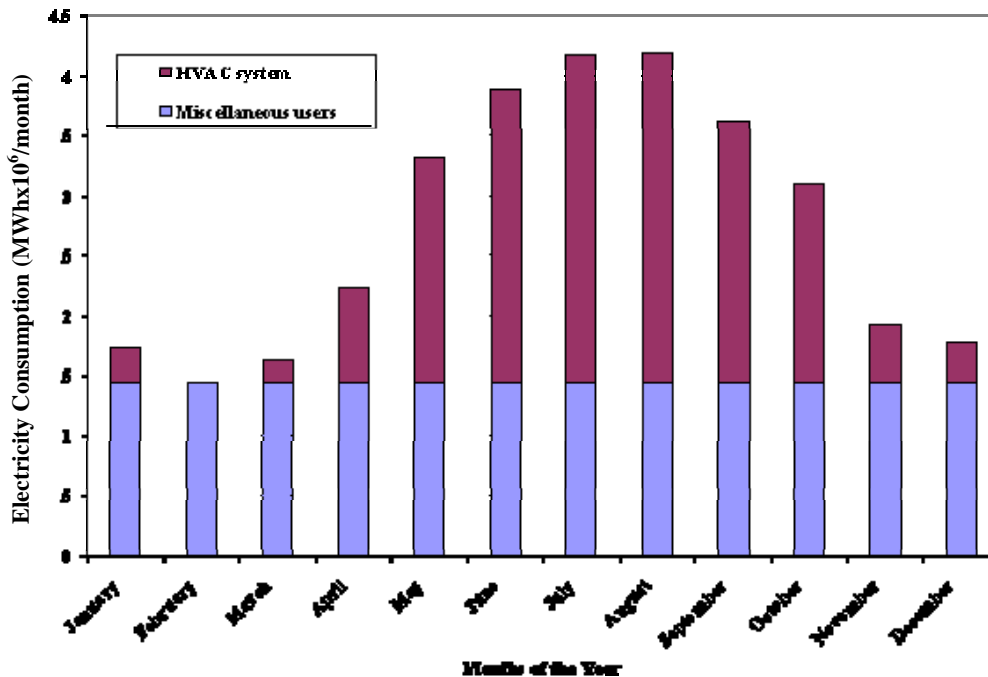
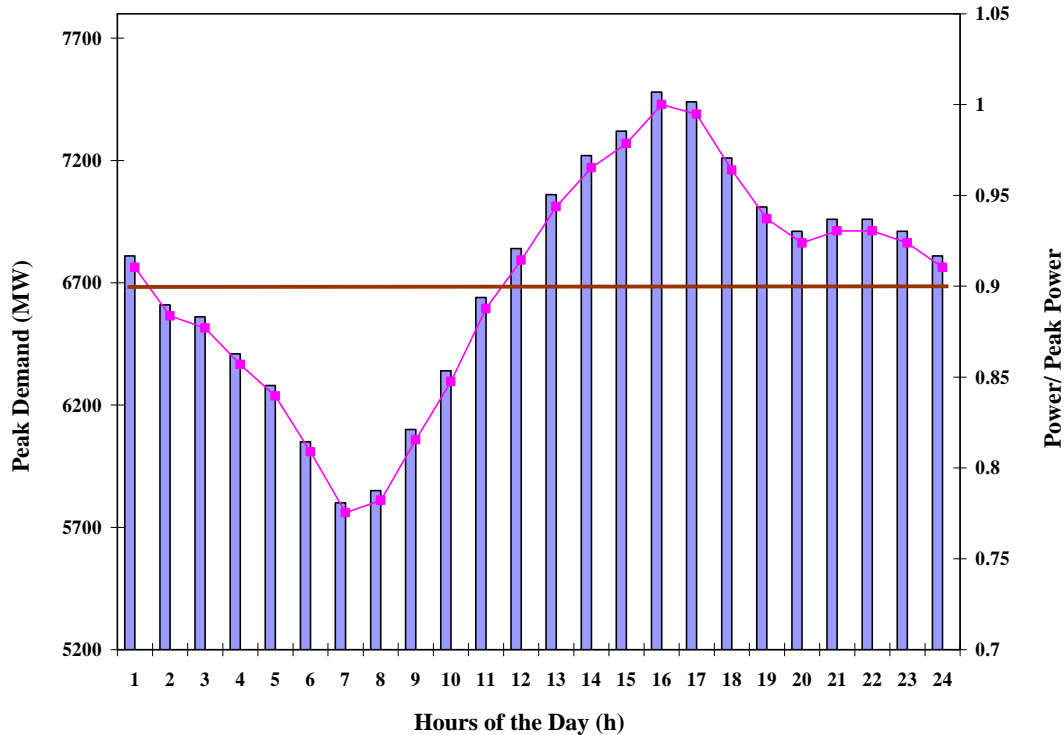


Figure 3. Monthly Electricity Consumption in Kuwait for 2003.



**Figure 4. Daily Electricity Consumption of a Peak Day in Kuwait for 2003.**

### 3. ENERGY CONSERVATION PROGRAM

This section explains advances made by the Buildings and Energy Technologies Department (BET), of the Environmental and Urban Development Division at Kuwait Institute for Scientific Research (KISR), to reduce energy consumption by developing and implementing an energy conservation program for Kuwait.

#### 3.1 MOE Code of Practice 1983

This code developed by KISR for MOE in 1983, requires a minimum insulation for walls and roofs, restricts the glazing areas for a given type of glazing, specifies a minimum ventilation rate, and controls the performance rating of different types of A/C systems. More importantly, by restricting the cooling demand or power requirement per unit area to exceed a specified value for a building and type of A/C system, it facilitates MOE to control the power supply to the buildings (MEW, 1983). By the end of 2001, country achieved a total saving of over 1.5 billion KD from reductions in installed capacity of A/C systems, demand of power plant for operation of A/C systems and fuel required to generate electricity needed to operate A/C systems [8].

#### 3.2 Future Energy Challenge for Kuwait

Although the 1983 energy conservation code is being applied to all new and renovated buildings, the peak power and electricity demand between 1995 and 2001 grew substantially at annual rate of 6.9 and 6.0%, respectively [6]. MOE is spending nearly 80 million Kuwaiti Dinars at 400 KD/kW every year to add additional power generation and distribution in the country to meet the growing power demand for A/C systems. Likewise, the amount spent annually on fuel to generate electricity for the operation of the A/C systems is well over 90 million KD (MOE, 2002) [9]. In addition, there are additional expenditures on manpower and material for the operation and maintenance of the power plants.

There have been significant developments over the last decade in new and more effective energy-efficient products and techniques that have resulted in considerable energy conservation worldwide. Continuing efforts in achieving better energy efficiency and to meet the objective of KISR's fifth strategic plan to reduce electricity consumption by 10%, BET department of KISR has been working for the development of an advanced code for energy conservation in A/C buildings under a MOE-

sponsored research program [10]. The buildings and the A/C systems to be constructed and designed after the revision and implementation of the code are likely to be significantly more energy-efficient, resulting in reduced demand for cooling equipment, new power plants, fuel bills and cleaner air and environment [7].

Although generation and distribution of electricity is a highly money-intensive process, a consumer in Kuwait is completely unconcerned as the electricity is available in abundance at highly subsidized rates, in which the consumer pays less than 15% of the actual cost of power and energy. Thus, the total responsibility for implementing conservation measures in Kuwait is with MOE.

**Table 2. Recommended power rating for different type of A/C systems.**

System	Power Ratings kW/RT							
	Type	RT	PR <sub>CHIL</sub>	PR <sub>CTF</sub>	PR <sub>CW</sub>	PR <sub>CHW</sub>	PR <sub>AH</sub>	PR <sub>T</sub>
Air-Cooled	<100	1.600				0.07	0.38	2.050
	100-250							
	>250							
Water - Cooled	<250	0.950	0.040	0.060	0.070	0.380	1.500	
	250-500	0.750					1.300	

Recently a model co-relating the peak load demand of a utility with the allowable power rating (PR) of air-conditioning (AC) systems has been developed in BET through a well defined methodology. The model is capable to predict the extent of allowable increase in the capital cost of the AC system for an improvement in PR from its base case as well. Furthermore, effectiveness of better PR of AC system for peak load management has been analyzed for Kuwait as a case study. It is found that up to 5,752 MW in reduction in peak load demand and savings of KD 2,301 million in capital expenditures are possible for the years between 2001 and 2025 if the PR of AC systems are improved to 1.2 kW/RT from its present level of 2.0 kW/RT. Also, it is estimated that extent of increase in capital cost of AC system by 106 % is justified for reducing the expenditure for new power plants. The findings will be useful for the energy planner and policy

#### 4. ENERGY CONSERVATION MEASURES (LOCAL CASE STUDIES)

##### 4.1 Efficient Cooling Systems

As an example of a more efficient cooling systems, power rating, the power required per unit of cooling (kW/RT), for package units has been reduced in the new code from 2.0 to 1.7 kW/RT. Similar reductions have been recommended for other types of A/C systems as illustrated in Table 2 [11]. In addition, larger use of chilled water systems with water-cooled condensers will help to reduce the demand for power and energy towards A/C in the country [12].

makers in the countries of Arabian Peninsula with huge demand for air-conditioning [13].

##### 4.2 Energy Audits in Buildings

Equally important are the findings of the energy audit studies conducted by BET in the Kuwait Port Authority building [14] and in KISR's main building that achieved a reduction of nearly 25% in annual electricity consumption by simple implementation of energy-efficient operation and maintenance strategies (O&MS) [15]. Furthermore, these studies revealed that an overcautious approach by HVAC designers resulting in over-sized equipment and insufficient reduction in parasitic power consumption of the auxiliaries during the lean cooling demand periods are two common features of A/C systems for most buildings in Kuwait. BET recently carried out a funded project by MOE for energy audit in three major buildings in Kuwait. The findings promise a

valuable savings in energy consumption. After a careful analysis of the major energy users for the ventilation and air-conditioning system for two weeks, energy conservation opportunities were identified. Operation of auxiliaries in line with cooling production and use of time-of-day control in relation to building occupancy were identified as two important energy efficient operation and maintenance strategies. Their implementation reduced the weekly energy consumption by 23% from 547 to 423 MWh/week [16].

#### 4.3 Time of Day Control Strategy

A programmable thermostat with multiple comfort-temperature options is a simple and low-cost device for saving energy, particularly in part-day occupancy buildings [17]. These devices have the facility to set a desired indoor temperature for different periods of the day and for different days of the week. Once programmed for the week with a desirable temperature offset during non-occupancy period, the device continues to save energy [18].

In government offices and other institutional buildings with limited periods of occupancy, A/C systems run around the clock to maintain comfort conditions. These important factors offer wide scope for energy conservation in these buildings. Implementation of appropriate energy-efficient O&MS such as time-of-day (TOD) control for the A/C systems and lighting can be very beneficial as their large-scale application is likely to impact the energy consumption scenario of the country. In a recent study conducted at an actual hospital building to implement a TOD control, the following results were obtained [19]:

- Nearly 55% reduction in daily demand from 2231 to 978 RTh/d.
- Over 55% reductions in daily energy consumption from 3393 to 1422 kWh/d.
- Indoor temperatures with TDC maintained at 24 C during occupancy period.
- Temperature build up in the building during non-occupancy period is within the acceptable levels 4 C.
- Duration of precooling should be sufficient to ensure that there is no adverse effect on the peak cooling demand and to provide adequate comfort to its user upon their arrival.
- Major reductions in peak power and cooling system capacity are possible by incorporating a cool storage. TDC for

buildings with part day occupancy along with use of cool storage (ice or chilled water storage systems) can offer major benefits to user and nation.

#### 4.4 Use of Ice Storage Systems

In countries around the world, cool storage is one method that is being used to curtail peak power demand of the national utilities which coincides with the peak summer season, as cooling of institutional, commercial and even residential buildings is becoming a must for modern living. Indeed, in the hot and arid countries of Arabian Peninsula and the Middle East, the peak power demand to meet the growing demand of A/C is a critical problem. In Kuwait, nearly 300-350 MW power is added every year only to satisfy the growing demand of the A/C systems. Furthermore, the hourly power demand profile, normalized with respect to its' peak for the peak demand day for the last five years, highlights that the daily average is nearly 90% of the peak value (MOE, 2003)[6]. This offers an opportunity to shave up to 10% of the peak power, i.e., more than 700 MW of peak power with cool storage and other power management techniques at the building and the equipment levels. Thereby, helping MOE to save large investment otherwise to be incurred on new power plants.

In a cool storage assisted A/C system, a programmable timer instead of a room thermostat operates the chiller of the A/C system to produce the required cooling. The chiller, thus, does not cool the building directly on an instantaneous demand basis; instead, it chills water or makes ice during the off-peak period of the utilities. The stored cooling effect in the form of chilled water or ice is used hours later, when cooling is needed especially during peak periods [20].

Based on a recent study conducted at a hospital building [20], which incorporate an ice storage system, to compare the performance of a conventional cooling versus an ice storage assisted air conditioning, findings based on the reported field trial runs conducted during the summer of 2003, promise a great benefit of using cool storage assisted A/C system. Building was cooled alternatively with conventional and ice storage-assisted mode and the field data were analyzed on a day-to-day basis. For days with nearly identical daily average dry bulb temperature the ice storage assisted-occupancy

delivered cooling at a rate of over 110.3RT with a single chiller producing 77.5 RT during the peak hour of the utilities. During this period the chiller drew 81.1 kW as compared to 149.7 kW consumed by two chillers in conventional mode of operation (fig. 6).

Thus, the ice storage assisted system achieved a reduction of 29.7 and 45.8% in the required capacity of cooling production system and in its peak power demand, respectively.

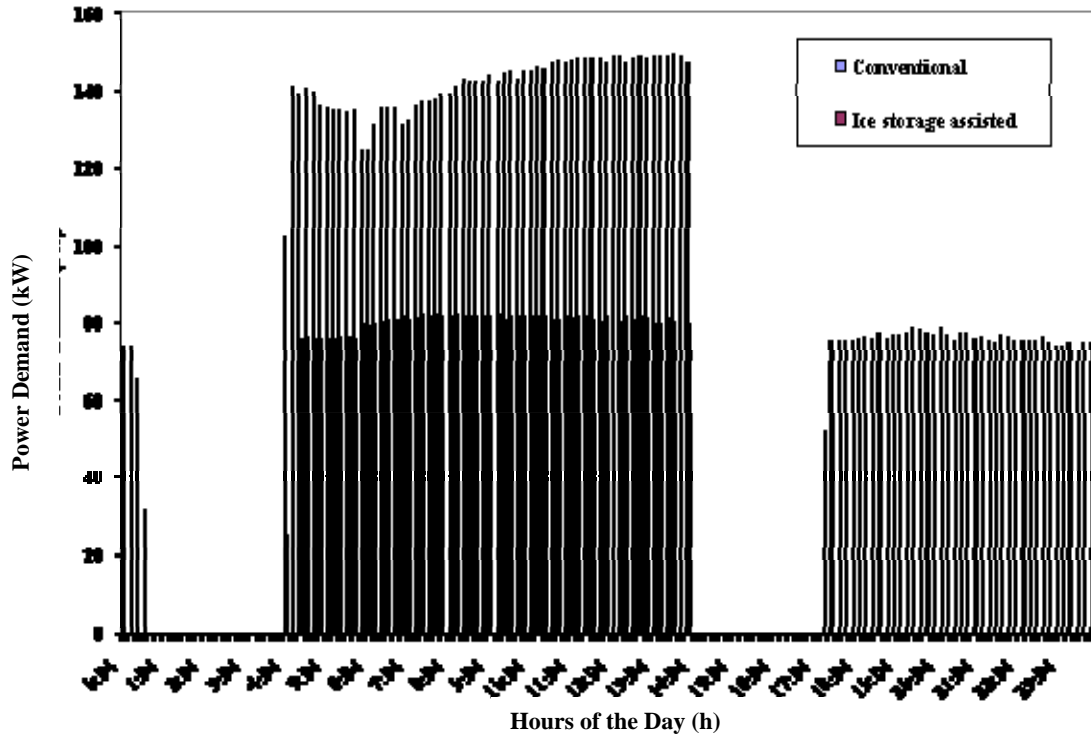


Figure 5. Power Demand Profiles for Days with Conventional and Ice Storage Assisted Cooling Modes.

## 5. RECOMMENDATIONS

The energy conservation projects conducted by BET achieved an important objective of KISR's 5<sup>th</sup> Strategic Plan 2000-2005, which is "to assess new technologies, materials and systems for enhanced energy conservation in domestic, industrial and commercial sectors, and implement pilot studies using available facilities, tools and databases to demonstrate the potential savings to be gained in their application; make appropriate recommendations for revision of codes on the basis of the studies." The successful completion of these projects provided essential guidelines to operate any central cooling system to achieve adequate comfort conditions during occupancy periods with minimum energy consumption.

It should be noted here that any savings in the electrical consumption would have an impact on reducing CO<sub>2</sub> concentrations. Based on data received from the power plants of MOE, for Kuwaiti conditions, for every Kwh of produced electricity, approximately 0.72 kg of CO<sub>2</sub> is formulated in the atmosphere.

Despite some improvements in energy efficiency over the last 12 years, Kuwait remains an energy-intensive country among other Middle Eastern countries. If it wants to maintain a place in a global and competitive world economy, it is important that Kuwait continues to improve its energy conservation and energy efficiency that will indeed lower the GHG emitted at the power plants leading to a better environment and cleaner and healthier air.



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