Demand Side Management (DSM)
For
Efficient Use of Energy in the Residential Sector in Kuwait:
Analysis of Options and Priorities

Azeez Nawaf Al-enezi, BSc, MSc.

Submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy

Institute of Energy and Sustainable Development,
De Montfort University, Leicester

October 2010

ABSTRACT

The State of Kuwait has one of the largest per capita consumption in the world, reaching 13061kWh in 2006 (Kuwait MEW, 2007). The power sector in Kuwait is not commercially viable, due to the current under-pricing policy and heavily subsidized tariff.

Kuwait needs to take action to meet the increased energy demand. A particular challenge is peak summer demand when extreme heat increases air conditioning loads. Peak demand reached 8900 MW in 2006, with a growth fast at an average rate 5.6% during the last decade. The generated energy reached 47605 GWh in 2006 and is growing fast at an average rate of 6.5%. Electricity demand is characterized by high seasonal variations and low load factor.

The main objective of this research is to assess and evaluate the most effective and robust Demand Side Management (DSM) measures that could achieve substantial reductions in peak demand and electricity consumption in the residential sector.

The residential sector in Kuwait consumes about 65% of total electricity consumption, and is characterized with inefficient use of energy due to several factors, including very cheap energy price and lack of awareness.

To achieve the research objective, an integrated approach was used, including the following steps:

- Performing a demand forecast and a building stock forecast across 10 years period (2010 -2019) for the residential sector. The main types of dwellings in Kuwait (villas, apartments and traditional houses) were considered in the forecast.
- Conducting detailed energy audits and measurements on selected typical models of residential dwellings. The aim of this process is to examine energy patterns and identify the potential energy efficiency DSM measures.

- Performing a simulation process, to evaluate energy performance of the audited dwellings and to estimate the potential DSM savings. Two basic scenarios were

considered in simulation, the first represents the base-case with actual existing condition and the second for different DSM options.

- Analysis of identified technological DSM options (five) and recommended policy DSM options (two) and ranking them in priority order using the Analytic Hierarchy Process (AHP).
- Estimate the potential energy savings and peak demand reductions by the implementation of identified DSM options. A building block approach is used to estimate the aggregate impacts of DSM options and its reflection on the country Load Duration Curve (LDC).

The research showed that a DSM portfolio consisting of the seven identified measures, and through a dedicated programme, could have substantial reductions in energy consumption and peak demand.

The research showed that the total accumulated energy savings across the forecast period was estimated at approximately 37229 GWh, and the total peak demand reductions during at the end of forecast (2019) reaches 1530 MW representing 8.9% Of the overall peak load.

With respect to the type of dwelling, the research also indicated that the total net revenues for the utility were estimated at: $292 million for villas, $79 million for apartments and $47 million for traditional houses.

One of the important indicators showed as a result of implementing the identified DSM measures is the positive environmental impact that could be achieved by reducing CO_2 total emissions by approximately 26.8 million tonne, which could achieve an annual income of about $38.9 million.

Integrated DSM policy recommendations were formulated, including gradual tariff adjustment, and more involvement by the utility, or government, in the creation of sustainable DSM programmes.

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ABREVIATIONS

AC	Air Conditioner(s)
AHP	Analytic Hierarchy Process
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
COP	Coefficient Of Performance
DBET	Department of Buildings and Energy Technologies
DOE	Department Of Energy (United States)
DSM	Demand Side Management
ECC	Energy Conservation Code
ECO	Energy Conservation Opportunity
EER	Energy Efficiency Ratio
EIA	Energy Information Administration
ESCO	Energy Service Company
EVM	Eigenvector Method
GB	Green Building
GDP	Gross Domestic Products
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GWh	Gegawatt hour
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
KD	Kuwaiti Dinar
KISR	Kuwait Institute for Scientific Research
kW	Kilowatt
kWh	Kilowatt hour
LDC	Load Duration Curve
MEW	Ministry Of Energy (Electricity and Water)
M toe	Million Ton Oil Equivalent
MW	Megawatt (1000 kW)
OECD	Organization for Economic Co-operation and Development Countries
SEER	Seasonal Energy Efficiency Ratio
TOE	Ton Oil Equivalent
TPES	Total Primary Energy Supply
UNDP	United Nations Development Programme
WB	World Bank

ACKNOWLEDGEMENTS

I am truly very grateful to Dr Andrew Wright and Dr Ibrahim Abdalla for the sincere help and the support during their supervision at my PhD study.

Considerable thanks go to Dr Greig Mill and Dr Simon Taylor for the assessment of my previous work at the annual review meetings.

Moreover, I express my gratitude for Dr Ali Alhmoud and Dr Ahmad Almulla in Kuwait Institute for Scientific Research for their advices and guidance.

Obviously I am grateful to Dr William Batty and Dr Simon Rees for their examination of my thesis.

Needless to say, I thank my colleagues and staff at IESD and the members in the Graduate School Office.

I am indebted to my family and relatives for their patience, love and encouragement.

CHAPTER 1

INTRODUCTION, RESEARCH MOTIVATION AND ORGANIZATION OF WORK

1.1 INRODUCTION

Utility demand-side management (DSM) is a way of managing the demand for power by encouraging the customers to modify their level or pattern of electricity usage. DSM was applied with some success in the developed countries and especially in the USA. At least 92 technologies were listed in the literature[1,2,3] ,that were used in the USA for providing strategic conservation, peak clipping, peak shifting, valley filling, flexible demand and strategic growth on the utility load shape.

In recent years, DSM has emerged as an efficient utility planning strategy for reducing capacity shortages and improving system load factors[4], although some controversy exists about the magnitude and precise cost-effectiveness of DSM implementation[5].

Nowadays, DSM is considered as an essential part of the Integrated Resource Planning (IRP) options to minimize social costs from the utility operation in meeting the future demand.

In Kuwait the problem of power shortage, and even programmed power cut, has been recently remarked due to the growing demand and the great waste of electrical energy. Potential energy efficiency improvements and on-peak reduction were highly recognize in several local studies and researches[6,7,8,9,10], however, no DSM programmes have been yet promoted.

The Ministry of Electricity and Water (MEW), is the only utility responsible for generation, transmission and distribution of electricity in Kuwait. It has to meet the growing demand for electricity by building new power plants that require high investments. MEW is vertically integrated and has five power plants use heavy oil and natural gas. The total installed capacity of MEW thermal power plants has reached 10313 MW in 2006, consisting of 9054 MW total capacity of steam turbine units and 1259 MW total capacity of gas turbine units[11].

The following table shows the development of installed capacity, maximum demand, Energy exported (sent out) to the grid and the load factor.

Table 1.1 Developments of Installed Capacity and Maximum Demand

Year	1996	1998	2000	2002	2004	2006	Avg. Growth Rate
Installed Capacity (MW)	6898	7389	9189	9189	9689	10313	3.75%
Maximum Demand (MW)	5200	5800	6450	7250	7750	8900	5.1%
Exported Energy (TWh)	21.7	25.8	27.5	31.1	35.6	47.6	7.15%
Load Factor (%)	55.8	59.1	57.1	57.2	60.6	61.1	0.9%

Source: The Ministry of Electricity and Water, Electrical Energy Statistical Year Book, 2007
TWh = 10^{12} Wh

The present research work focuses on the potential DSM measures for the residential sector and the evaluation of their impacts on the on-peak demand and energy consumption from 2010 to 2019 (inclusive).

1.2 Research Motivation

The key motivating issues for this research work are:

- From Table 1.1, it is clear, that the peak demand in Kuwait increased from 5200 MW in 1996 to 8900 MW in 2006, with an average growth rate about 5.1%. In contrast, the average growth rate of maximum demand in most of the industrial countries does not exceed 2-3%.
  Based on MEW Statistical Year Book, the maximum load share per capita reached 2796 watts in 2006. Thus, MEW is facing great challenges; first to satisfy the requirements of large investments for building new power plants, and second to take the necessary actions for rational use of energy and decrease the rate of electricity demand.
- Energy efficiency indicators provided by IEA show that Kuwait has, relatively, much higher energy intensity. The energy intensity is expressed as the energy content per GDP; for Kuwait the energy intensity for 2004 was 0.58 toe/GDP

Thousand \$2000, while the world average is 0.29 and the OECD average is 0.19 toe/GDP Thousand \$2000[12].

- The net electricity generation in Kuwait reached 13061 kWh per capita in 2006. By international comparison, this level is extremely high. According to IEA statistics, the world average of electricity consumption per capita is only 2516 kWh. This means that Kuwait's per capita electricity consumption is about 5 times the world average[13].
- In Kuwait, the power sector is not commercially viable, due to the current under-pricing policy and heavily subsidized tariff. MEW charges a flat tariff rate 2 fils (≈ US¢ 0.60)/kWh to almost all consumers, except for the owners of beach cabins (chalets), they have to pay more (10 fils/ kWh). For all consumers no demand charges are paid. Under these circumstances of cheap electricity prices the consumers in Kuwait do not use electricity in an efficient way.
- Since the residential sector in Kuwait is the major consumer of electricity and it is responsible for about 65% of total electricity consumption (estimated at 21 TWh in 2003), it is expected to have a good potential for DSM.

1.3 Research Objective

The core objective of this work is to assess and evaluate the most effective and robust DSM measures that could achieve substantial reductions in peak demand and electricity consumption in the residential sector.

1.4 Basic and Specific Research Questions

The basic research question could be formulated as follows:

What are the demand side management techniques, including technology measures and policies which could be implemented in the residential sector and lead to a substantial reduction in peak demand and energy consumption?

Consequently, the following specific questions have to be answered:

a) What will be the future energy use in the absence of any DSM activities?
b) How can demand side management resources offset the need for new power plants in Kuwait?

c) What are the potential DSM priority options that could be applied in the residential sector?

d) What would be the impact of selected DSM options on summer peak demand and Energy consumption?

e) Are the "most effective" identified DSM options robust enough when examined against various uncertainties, such as demand growth, current and future technology, policy and economic changes?

f) What applicable regulatory policy reforms are needed?

The expression "most effective" DSM options needs to be clarified since it will be repeated throughout the research study. Generally DSM is a win-win technique that is with its successful implementation, it has to be cost-effective to both consumers and utility. This objective is very difficult to fulfil in Kuwait, since electricity is heavily subsidized, consequently, consumers are not interested to invest any money in energy efficiency projects. Thus, criteria of evaluating the DSM options could be based on avoided costs.

The above specific questions emphasize the importance of better understanding of the characteristics of electricity consumption in the residential sector and the expected future impacts of implementation of DSM options.

1.5 Research Methodology

The methodology employed to evaluate DSM impacts on utility generation planning, must consider two fundamental issues:

(i) How to identify and estimate the "most effective" DSM options and their impact on electricity demand over a certain period of time.

(ii) How to incorporate these impacts in the supply – side planning process and evaluate their capacity savings, financial benefits and GHG mitigation.

The methodology used for this purpose will be based on the following steps:

- Data collection and review of literature and studies applied to the residential sector.
- Select typical buildings from the sector for energy simulation.
- Make the necessary analysis to identify the DSM portfolio.

- Develop a baseline scenario and demand forecast for the period 2010 to 2019.
- Apply the analytic hierarchy process (AHP) to evaluate and put in priority order the identified DSM options.
- Reflect the cumulative DSM impacts on the overall load duration curve through the considered 10 years period of forecast 2010-2019.

1.6 Summary

In the last decades, the electrical energy consumption as well as peak demand in Kuwait have increased with a high growth rate due to the rapid development and heavily subsidy of electricity costs. The per capita electricity consumption reached 13061 kWh in 2006, which is eight times the world average and the fourth highest level in the world. The growth rate of peak demand and electricity consumption ranges approximately from 5% to 7% representing one of the highest rates in the world. These issues and others are strong motivation for the present research. In such a situation, the DSM may be the best solution. But this means it should be studied carefully before considering implementation.

The objective of this research work is to assess and evaluate the most effective and robust DSM measures that could achieve substantial reductions in peak demand and electricity consumption. The DSM measures will include both technology and policy options. To achieve this objective, an integrated approach will be used including the following steps: data collection, energy audits and simulation, demand forecast, identification of potential DSM options, ranking options using AHP, and building block approach.

CHAPTER 2

DSM BACKGROUND AND TECHNIQUES

2.1 The Concept of DSM

The concept of Demand Side Management originated in the 1970's in response to the impacts of energy shocks to the electricity utility industry (EIA, 1995)[14]. As the fuel prices sharply increased, accompanied with high inflation and interest rates, the high cost in building, financing and operating power plants and the resulting rate increase had forced the rising of awareness of accurate demand projection and energy resource conservation.

Originally, the term "Demand side management" was focused on the utility demand side, as opposed to the traditional supply side options; however, the implication, application and measures of utility DSM have evolved over the years.

In this chapter, the widely accepted definition and concepts of DSM in the power market research literature are introduced and the DSM techniques and research are briefly described. This chapter also includes a review of DSM activities in Kuwait and a literature review.

Demand side management is the planning and implementation of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape – i.e., in the time pattern and magnitude of utility's load. Utility programmes falling under the umbrella of demand side management include load management, new uses, strategic conservation, electrification, customer generation and adjustment in market share[15].

Benefits and Implications of DSM

The various benefits of DSM to consumers, enterprises, utilities, and society are to[16]:

- Improve the efficiency of energy systems.
- Reduce heavy investments in new power plants, transmission, and distribution network.
- Minimize adverse environmental impacts.
- Reduce power shortages and power cuts.

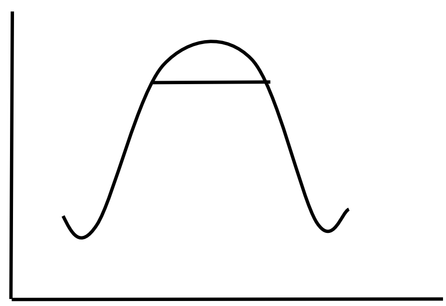
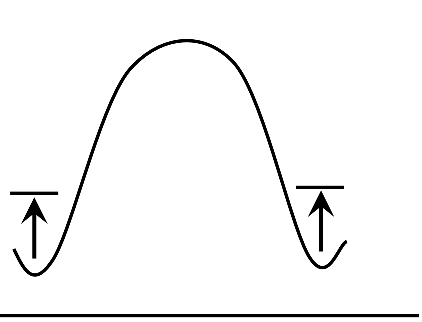
- Lower the cost of delivered energy to customers.
- Improve the reliability and quality of power supply.
- Contribute to local economic development.
- Creation of long-term jobs due to new innovations and technologies.

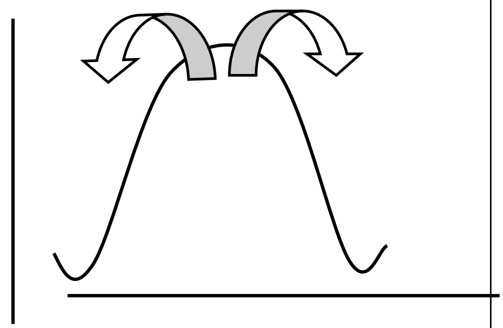
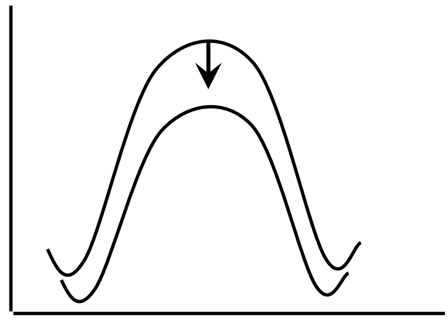
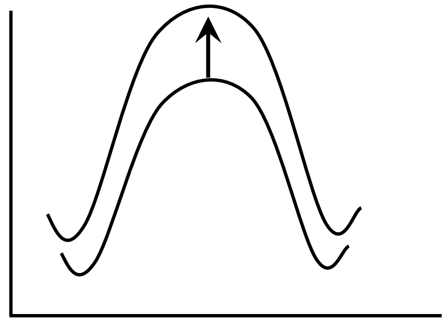
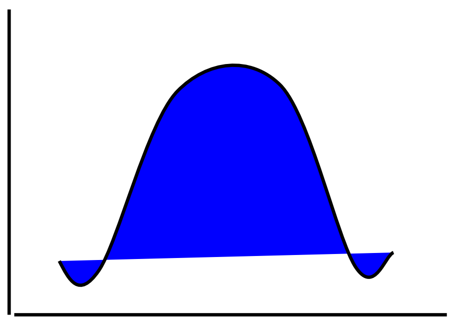
2.2 Standard DSM Load Shape Objectives

Based on the state of the existing utility system, the load shape objectives can be characterized into six categories (Gellings and Chamberlin, 1993, 2nd ed.)[17]

Although, the research is focusing more on some DSM measures than others, Gellings and Chamberlin' six generic load shape objectives are described in detail below as this categorization provides clear conceptual bases for load management. Note that these forms of load shape objectives are not mutually exclusive and often are employed as combinations. Load shape change objectives adapted from Gellings (Gellings, 1982) are illustrated in Figure 2.1.

Figure 2.1 Standard DSM Load – Shape Objectives

a) <u>Peak Clipping</u> Peak clipping refers to the reduction of utility loads during peak demand periods. This can defer the need for additional generation capacity. The net effect is a reduction in both peak demand and total energy consumption. The method usually used for peak clipping is by direct utility control of consumer appliances or end-use equipment.	
b) <u>Valley Filling</u> Valley filling is a form of load management that entails building of off-peak loads. This is often the case when there is underutilized capacity that can operate on low cost fuels. The net effect is an increase in total energy consumption, but no increase in peak demand. A typical example for the creation of valley filling is the energy thermal storage.	

c) Load Shifting Load shifting involves shifting load from on-peak to off-peak periods. The net effect is a decrease in peak demand, but no change in total energy consumption. Typical methods used for load shifting are the time-of-use (TOU) rates and/or the use of storage devices.	
d) Strategic Conservation Strategic conservation refers to the reduction in end-use consumption. There are net reductions in both peak demand (depending on coincidence factor) and total energy consumption. Examples of strategic conservation efforts are appliances efficiency improvement and building energy conservation.	
e) Strategic Load Growth Strategic load growth consists of an increase in overall sales. The net effect is an increase in both peak demand and total energy consumption. Examples of strategic load growth include electrification, commercial and industrial process heating and other means for increase in energy intensity in industrial and commercial sectors.	
f) Flexible Load Shape Flexible load shape refers to variations in reliability or quantity of service. Instead of influencing load shape on permanent basis, the utility has the option to interrupt loads when necessary. There may be a net reduction in peak demand and little if any change in total energy consumption.	

The primary objective in each case of figure 2.1 is to manipulate the timing or level of customer demand in order to accomplish the desired load objective. For example, in the case of under-utilized capacity, valley filling may be desirable. On the other hand, in countries, such as Kuwait, with rapidly growing demand, peak clipping or strategic conservation can be used to defer costly new capacity additions, improve customer service, reduce undesirable environmental impacts, and maximize national economic benefits.

2.3 Conceptual Basis of DSM Research

DSM emerged at the time when the energy resource depletion and environmental pollution became of great concern. Although, the core philosophy of DSM has been initiated for changing the managerial practices of electricity industry, it is coherent with the whole national plan for sustainable development and environmental protection.

The complex nature of modern electricity planning, which must satisfy multiple economic, social and environmental objectives, requires the application of a planning process that integrates these often conflicting objectives and considers the widest possible range of traditional and alternative energy resources.

Currently, the concept of DSM is connected with more conceptual pillars such as *integrated resource planning (IRP), and Sustainable consumption patterns.*

a) Integrated Resource Planning (IRP)

IRP is a long-term planning process that allows electric utilities to compare consistently the cost-effectiveness of all resource alternatives on both the demand and supply side, taking into account their different financial, environmental and reliability characteristics. If applied properly, IRP leads to the most cost-effective electric power resource mix, reducing the financial requirements to satisfy electric power service need. IRP is especially useful as a planning tool in growing economies that have increasing electric generating capacity needs and, consequently, high power supply costs.

b) Sustainability and Sustainable Consumption Patterns

Sustainable consumption patterns have been recognized as one of the essential concepts of sustainable development by the international community. Agenda 21, as the leading international cooperative efforts to push forward sustainable development, stresses the need to change sustainable patterns of consumption and production, reinforces values that encourage sustainable consumption patterns and lifestyles, and urges the study and promotion of sustainable consumption by governments and private sector organizations (UNEP, 1992)[18]:

'Considerations should be given to the present concepts of economic growth and the need for new concepts of wealth and prosperity which allow higher standards of living through changed lifestyles and are less dependent on the Earth's finite resources and more in harmony with the Earth's carrying capacity'. And achieving the goals of environmental quality and sustainable development will require efficiency in production and changes in consumption patterns in order to emphasize optimization of resource use and minimization of waste" (UNEP, 1992) .

2.4 World Experience in DSM and Lessons Learned

Experience in DSM varies widely between countries; since early 80's, DSM activity started in the USA and followed by many countries[19]. More than 30 countries around the world have successfully applied DSM to increase energy savings, reduce the need for new power plants, improve economy and reliability in power network operation, control tariff escalation, save energy resources and improve environmental quality.

The purpose of this section is to examine the experience in DSM programmes of some utilities and governments, as well as lessons learned for future DSM programme implementation. This section will cover the experience of USA, West Europe and two countries selected from the developing world: Thailand and Egypt

2.4.1 *Experience of USA*

Energy efficiency has made a tremendous contribution to the economic growth of the United States since the oil crises of 1973. Total US primary energy use per capita in 2000 was almost identical to that of 1973. Yet over the same time period, economic output (GDP) per capita increased 74 percent (Nadel and Geller 2001). By 2000, reduced "energy intensity" (compared with 1975) was providing 40 percent of all US energy services. This made energy efficiency America's largest and fastest growing energy resource – greater than oil, gas, coal, or nuclear power. Since 1973, the United States has received more than four times as much new energy from savings as from all net expansions of domestic energy supply combined (Lovins 2002).

In 2000, the US consumers and businesses spent more than US$600 billion for total energy use. Had the United States not dramatically reduced its energy intensity since 1973, they would have spent at least US$430 per capita more in energy purchases in 2000 (Nadel and Geller 2001).

Over the last two decades in the United States, many states used IRP to compare the benefits and costs of additional generation. These IRP programmes led states to generate a network of utility DSM programmes that together avoided the need for about 100 power plants with 300 MW (Prindle 2001). The average initial cost of efficiency was less than one-half the cost of building new power plants. Utilities report that their average cost of implementing electricity savings of all kinds has been about 2 cents per kWh. In comparison, each kWh generated by an existing power plant costs more than 5 cents. Delivered power from a nuclear plant cost as much as 20 cents per kWh (Lovins 2000).

In the late 1980s, more than 1,300 DSM programmes were conducted in the United States, which together reduced the peak load by 0.4 to 1.4 percent, corresponding to a demand growth rate of 20 to 40 percent[20]. Between 1985 and 1995, more than 500 utilities conducted DSM programmes, achieving a reduction in peak load 29 GW. Up to the mid 1990s, US utilities increased their investment in DSM each year, from US$900 million in 1990 to US$2,700 million in 1994, corresponding to 0.7 to 1 percent of average sales revenue.

The uncertainty brought on by impending electric industry restructuring caused DSM spending to drop dramatically during the 1990s. Total US utility spending on all DSM programmes (energy efficiency and peak load reduction) fell by more than 50 percent. Yet a total of US$1.4 billion was still spent on utility energy efficiency programmes in 1999, due to the adoption of system benefit charges (Nadel 2000).

To promote DSM and help to fund the DSM programmes, financial incentives have often stipulated by mandates (Sioshansi, 1995, EIA, 1994)[21]. Common incentives offered to sustain the utility companies' DSM activities are:

- Raising tariffs to pay for DSM initiatives
- Taking profits from the utility DSM services.
- Mechanisms to recover lost of profit from energy conservation activities.

Based on EIA reports, the state of California, USA, has achieved a peak reduction of 4,500 MW to 5,500 MW, which turns out to be 11-14 percent of its peak demand, through utility-sponsored DSM measures. This fairly large saving has been achieved through utility actions in response to the directives of the US regulatory commissions. During a power crisis around 2001, the voluntary DSM supported by tariff concessions (for reduced consumption) substantially increased the savings to about 6,500 MW. In the absence of such major savings, the energy crisis in California could have been much worse.

In 2000, 962 electric utilities in USA report having DSM programmes. Of these, 516 are classified as large, and 446 are classified as small utilities (large utilities are those reporting sales to ultimate consumers and sales for resale greater than or equal to 150,000 MWh, while small utilities with sales to ultimate consumers and sales for resale of less than 150,000 MWh). This is an increase of 114 utilities from 1999. DSM costs increased to US$1.6 billion from US$1.4 billion in 1999.

Since 1992, the US regulatory commissions have been monitoring the peak load reduction and energy saved due to DSM programmes initiated by the large power utilities. The US Department of Energy (DOE) data shows that the USA achieved a reduction of 23,000 MW to 30,000 MW and energy saving of 54,000 million kWh to 60,000 million kWh due to energy efficiency programmes initiated by utilities.

This saving does not include the reduction in demand due to the appliance efficiency standards, actions initiated by individual consumer/industry (such as energy audit), the savings due to tighter norms for construction of buildings or the load management programmes. Moreover, nearly two-thirds of the peak as well as energy saving came from residential and commercial consumers (EIA-861, "Annual Electric Power Industry Report", December, 2003).

Table 2.1 below presents the results of selected DSM programmes applied in several states. A key criterion for selecting these examples is that the programmes used some kind of ex-post measurement of peak demand impacts to estimate the overall programme impact. As shown in the table, the summary of these case studies demonstrate and document significant peak demand and energy savings.

Table 2.1 - Energy and Peak Demand Savings of Selected Programmes in USA

State	Programme Name	Annual Energy Savings (MWh)	Peak Demand Savings (MW)	MW/GWh*
CA	San Francisco Peak Energy Programme	56,768	9.1	0.16
CA	Northern California Power Agency SB5x Programme	37,300	15.9	0.44
CA	California Appliance Early Retirement and Recycling Programme	--	--	--
TX	Air Conditioner Installer and Information Programme	20,421	15.7	0.77
FL	High Efficiency Air Conditioner Replacement (residential load research project)	--	--	--
CA	Comprehensive Hand-to-Reach Mobile Home Energy Saving Local Programme	7,681	3.7	0.48
MA	NSTAR Small Commercial/Industrial Retrofit Programme	27,134	6.0	0.22
MA	2003 Small Business Lighting Retrofit Programme	35,775	9.7	0.27
MA	National Grid 2003 Custom HVAC Installations	980	0.17	0.17
NY	New York Energy Smart^{SM} Peak Load Reduction Programme	--	--	--
MA	National Grid 2003 Compressed Air Prescriptive Rebate Programme	673	0.098	0.15
MA	National Grid 2004 Energy Initiative Programme – Lighting Fixture Impacts	36,007	6.5	0.18
MA	National Grid 2004 Energy Initiative and Design 2000plus: Custom Lighting Impact Study	1,593	0.266	0.17

* This column is derived values from reported peak demand savings and annual energy savings.

Source: ACEEE, D. York, M. Kushler & P. Witte "Examining the Peak Demand Impacts of Energy Efficiency": A Review of Program Experience and Industry Practices.

2.4.2 *Experience of European Union*

In contrast to the large, privately owned, and vertically integrated utilities which are characteristic of the USA, the ownership, structure and regulatory set up of European Union (EU) utilities varies tremendously. While countries such as France, Greece, Ireland and Italy have state owned utilities, with regulatory oversight by an appropriate ministry; privately owned utilities exist in Belgium, Denmark and the UK. The latter have more regulatory oversight through agencies or communities composed of various government, utility and trade union representatives. Remaining EU utilities have mixed ownership structure. Since 1989, the European Commission (EC) had set up a range of energy efficiency and renewable energy initiatives aiming to stabilize CO2 Emissions at the 1990 level.

As part of it's SAVE programmes for energy conservation measures, the EC's Energy Directorate commissioned 26 studies evaluating the possibilities for IRP and DSM programmes in region throughout the EU (Fee, 1994). Most of these studies confirm that there is an attractive and cost-effective DSM resource available, but indicate that a range of policy and legislative changes are required to provide utility incentives to capture them.

Between 1987 and 1991, a wide variety of CFL-DSM programmes were carried out in Europe. These impacted 7.4 million households through 52 schemes in 11 countries. The average societal cost of energy resulted from these programmes was US$0.021/kWh (50% of the generation cost).

2.4.3 *Experience of United Kingdom*

In 1992, following electric sector restructuring, the UK established an independent, non profit Energy Saving Trust (EST) to design and oversee DSM programmes. Its primary mandate was to reduce carbon dioxide emissions through energy efficiency. During the first four years of the DSM programme, the UK power sector collected US$ 165 million from a wires surcharge, or system benefit charge, and invested it in more than 500 energy efficiency projects. Estimated electricity savings totalled more than 6,800 GWh, which is equivalent to the annual electricity consumption of 2 million UK households[22].

Under the UK Utilities Act of 2000, both gas and electricity suppliers are required to meet specific energy efficiency targets and encourage or assist domestic customers to implement energy efficiency measures. The overall energy savings target (known as the Energy Efficiency Commitment) is 62 TWh, with half the savings targeted at customers receiving benefits or tax credits. The government regulator is responsible for administering the commitment, apportion the overall target to each supplier, determine which EE measures quality, quantify savings, and monitor suppliers' performance against their targets (IEA 2003).

2.4.4 *Experience of Thailand*

Within South-east Asia, the most extensive utility DSM programmes implementation has been successfully implemented in Thailand.

In 1991, Thailand became the first Asian country to formally approve a countrywide DSM plan. The Thai DSM programmes got under way in late 1993, and the DSM Office now has a staff of 100 who are developing residential, commercial, and industrial energy efficiency programmes. Beginning in 1992, Thailand also initiated a national energy conservation law, supplemented by a US$80 million annual fund, separate from the DSM effort, to finance investments in energy efficiency throughout the economy[23].

The utility-sponsored DSM effort in Thailand was spurred by a 1990 directive by the National Energy Policy Committee to the three state-owned electric utilities to develop a DSM Master Plan by mid-1991. Thailand has a state-owned generating utility, the Electricity Generating Authority of Thailand (EGAT), and two state-run distribution utilities, the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). With assistance from the International Institute for Energy Conservation (IIEC), the three utilities developed and submitted a plan which was approved by government in November 1991[24]. The five-year plan called for an investment of US$ 189 million to achieve a peak demand reduction of 225 MW and energy savings of 1080 GWh/year at a cost-of-saved (CSE) of less than half of the utilities' long-run marginal supply cost.

At the time the DSM programme was established, Thailand has no experience with designing or implementing DSM programmes. As a result, the World Bank, in partnership with the United Nations Development Programme (UNDP) and IIEC assisted EGAT in developing initial programme strategies.

During the first few years of programme implementation, EGAT decided to launch a few initiatives first, in order to gain experience and build-in-house capabilities, before expanding its activities. Thus, between 1993-1996, The DSM Office initiated four programmes to address energy for lighting, refrigerators, air conditioners and commercial buildings. The implementation process of these initial DSM programmes as well as the results achieved are described in details in the case study of Thailand presented by J. Singh and C. Mulholland[25] and are summarized below.

High Efficiency Lighting:

This programme was focused on the fluorescent tube lamps (FTL) which share about 20 percent of electricity consumption attributed to lighting and increases 10 percent per year in sales.

To promote the use of high efficiency T-8, 36W/18W, FTLs (thin tubes) instead of T-12, 40W/20W, EGAT through the DSM Office negotiated directly with manufacturers and allocated US$ 8 million to support the cost of public campaign, using major stars and TV advertisement and to educate the public about the benefits of these "thin tubes". Within one year, all manufacturers (five in 1993) had completely switched production to thin tube lamps and EGAT's advertising campaign substantially facilitated and even accelerated public acceptance of this transition. Shortly thereafter, the one major importer of FTLs had also complied with the agreement to discontinue distribution of T-12 lamps. This effective partnership with manufacturers provided the DSM Office with a positive track record and experience that it then used to launch its subsequent programmes.

Refrigerators:

Building upon its experience and success with FTLs, the DSM Office approached the five domestic manufacturers of refrigerators in early 1994 and negotiated a voluntary labelling scheme for all single-door models (150-180 litres). The labelling scheme used a rating scale, with the un-weighted market average of 485 kWh/yr (with load) as a level 3 (models with consumption within 10 percent of the average receive level 3 label).

As with the FTLs programme, EGAT sponsored a large publicity campaign to educate consumers about the energy labels and aggressively promoted the level 5 label (with 25% less than the mean). Since many of the level 5 models only had a marginal incremental cost, no financial incentives were offered by the DSM Office to the consumers.

In early 1998, the DSM Office worked with the Thai Consumer Protection Agency and made single-door refrigerator mandatory and in early 1999, the DSM reached agreement with the manufacturers to increase the requirements for each label level for single-door models by 20% by January 2001.

The DSM Office estimates that about 84 percent of all refrigerators sold in Thailand now have the level 5 label and that the programme has contributed to a 21 percent reduction in overall refrigerator energy consumption. On average, Thailand is slightly less efficient than those for the "Energy Star" label in the US.

Air Conditioners:

In late 1995, the DSM Office targeted air conditioners (ACs) as its next end-use and proposed a voluntary label system similar to the refrigerator scheme. The labels were based on an energy efficiency ratio (EER) of 7.4, which represented the average of models sold locally, and rated on a scale similar to the refrigerators. The Thailand Industrial Standard Institute (TISI) tested the models, including both split-system and unitary (window) models (the programme initially included capacities from 2.052-7.034 kW and incorporated sizes up to 8.792 kW in late 1999), and the DSM Office began supplying labels to the manufacturers by early 1996.

Practices in this label programme, showed that level 5 ACs were considerably more challenging to promote than the refrigerators. In contrast to small number of FTL and refrigerator manufacturers, the Thai AC industry was more diverse and fragmented, with more than 55 different manufacturers, many of which are small, local assembly operations. And, the incremental cost for higher level ACs was significant.

Due to the higher incremental cost, the DSM Office estimates that only 38 percent of ACs have a level 5 labels and none of the lower efficiency models are labelled at all. Despite EGAT receiving approval from the DSM Sub-Committee to make AC labels mandatory in early 1999, the DSM Office has been unable to reach agreement with the AC industry on a suitable timetable for mandatory labels or increased requirements for each level of the label scheme. Without this agreement, it is unclear how further efficiency gain or energy savings impacts can be achieved under this programme.

Overall Impact Results:

Table 2.2 shows the DSM programmes savings achieved during the period 1993-June 2000. It is clear that EGAT exceeded their overall targets. These programmes have resulted in an aggregate peak load reduction of 566 MW, or 4 percent of EGAT's total 1999 capacity, and cumulative annual energy savings of 3,140 GWh, representing more than double the original energy savings Programme targets. The Programme also reduced CO2 emissions by 2.32 million tons per year.

Table 2.2 – DSM Programme Savings in Thailand Thorough June 2000

Programme	**Launch Date**	**Savings Targets**			**Evaluated Results**			**Percent of Target Achieved**		
		Peak (MW)	Energy (GWh/yr)	CO_2 (tons)	Peak (MW)	Energy (GWh/yr)	CO_2 (tons)	Peak (%)	Energy (%)	CO_2 (%)
Lighting	Sep.1993	139	759	--	399	1973	1457807	287	260	
Refrigerators	Sep.1994	27	186	--	84	849	627365	310	456	
Air Conditioners	Sep.1995	22	117	--	84	318	235314	381	272	
Motors	Dec.1996	30	225	--	--	--		--	--	
Green Buildings	Oct.1995	20	140	--	--	--		--	--	
Total		**238**	**1427**	**116000**			**2320486**	**238**	**220**	**200**

<u>Source:</u> "DSM in Thailand: A Case Study", J. Singh and C. Mulholland, Oct. 2000

Regardless of the objectives and mechanisms a country might prefer, Thailand's programme offers considerable insight into the major issues associated with implementing DSM programmes, and of the potential benefits that can accrue. Not all of its DSM programmes have achieved their intended impacts, but EGAT achieved its overall peak and energy reduction goals at a cost far less than would have been needed to add new generation during this period, benefiting the country from an economic point of view.

2.4.5 *Experience of Egypt*

Egypt has a long experience in energy efficiency improvement since the establishment of the Organization of Energy Planning (OEP) in 1983, as an independent legal entity related to the Ministry of Petroleum. The main activities of OEP comprise: energy planning and analysis on the national and sector level, energy conservation and efficiency improvement, energy information management including publishing an annual energy statistics report, and human resources development and training for energy users.

This experience has been enhanced through an energy conservation project: "Energy Conservation and Environment Protection" (ECEP), covered the period from

1989 to 1998, sponsored by US-AID, and implemented by the following local agencies[26]:

- Tabbin Institute for Metallurgical Studies (TIMS).
- Development Research and Technological Planning Centre (DRTPC).
- Federation of Egyptian Industries (FEI).

The objectives of ECEP project are to improve the efficiency of energy use, plan and implement a pilot DSM programme as well as the development of technical expertise in the various energy fields. The project activities were focused on the industrial sector (private and Public), however, some energy efficiency improvement activities were made in the commercial sector.

Within the ECEP framework, a four-phased approach was outlined to permit establishing basic knowledge and strategy options that can then guide a subsequent focus on how to achieve the most promising opportunities for DSM and energy efficiency. Figure 2.3 shows the recommended four-phased approach to DSM planning and implementation in Egypt. The four phases consist of:

- Phase 1: an initial feasibility assessment (second half of 1994),
- Phase 2: a 1 – year or longer options and development phase,
- Phase 3: a 4-6 month DSM plan development phase; and
- A longer term implementation phase.

The feasibility and development phases are specifically intended to ensure that the DSM and energy efficiency ideas employed around the world are first verified to be feasible or appropriate in Egypt before detailed analysis of Egypt's energy resource planning process is performed.

The DSM pilot programme was launched formally in May 1996. However, work had progressed for several months before then to select industrial sites and train personnel in preparation for energy audits. Training course was provided to engineers from the Egyptian Electricity Authority "EEA" (changed now to Egyptian Electricity Holding Company "EEHC", and the Alexandria Electricity Distribution Company "AEDC".

The DSM Working Group selected 12 plants to demonstrate the DSM potential in major industrial sub-sectors. They include metal, textile, chemical, cement, beverage, plastic, and ceramic industries. The group added one hotel to represent a large commercial building. This distribution of activities helped the DSM Working Group to plan future activities that may target certain sectors specifically.

The next phase was to conduct energy audits and identify the DSM measures and the projects to be implemented. ECEP assisted plants to specify, procure and to install energy saving projects. Examples of these projects are:

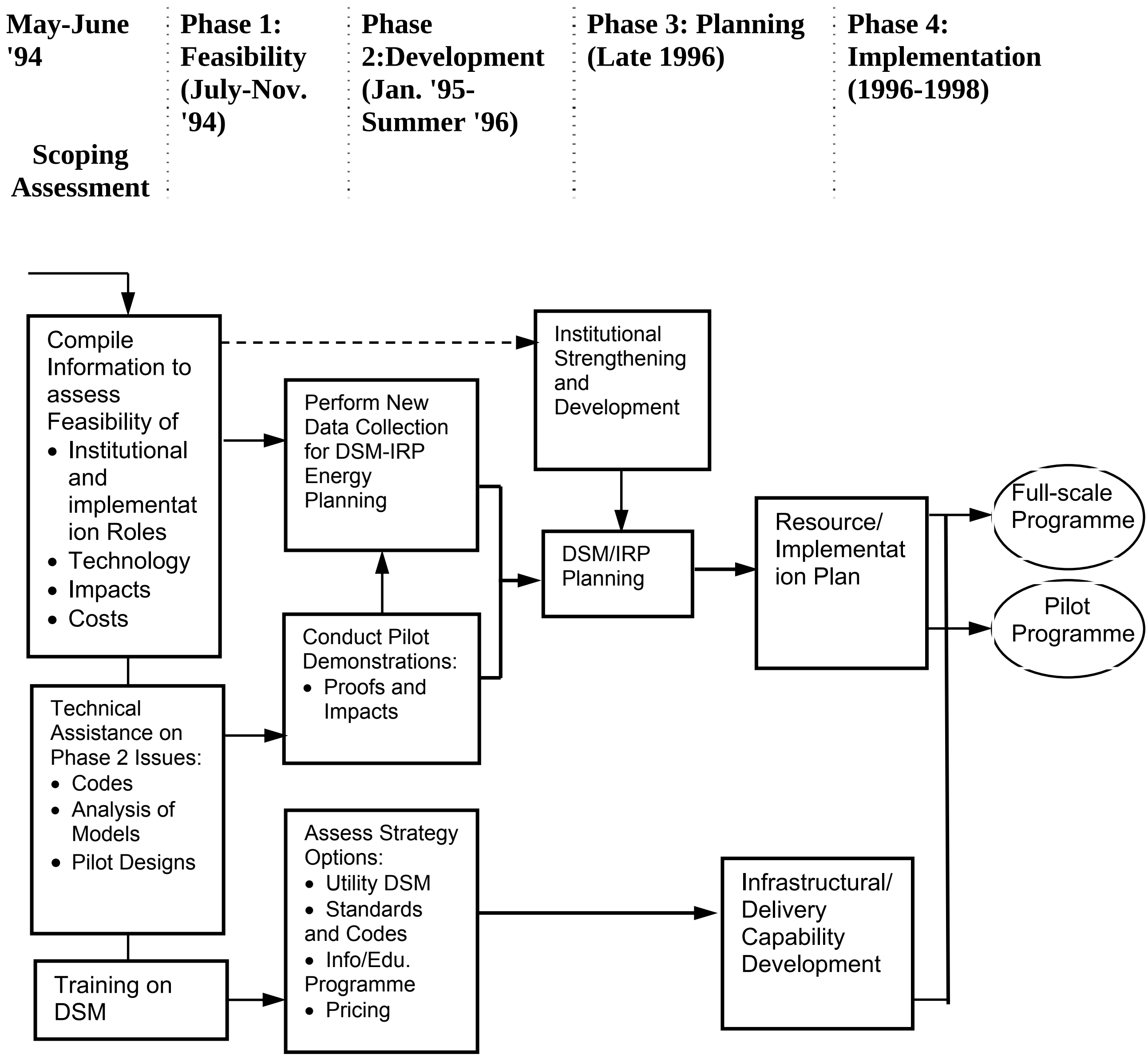
- High efficiency fluorescent lighting and electronic ballasts.
- Installation of many low cost measures such as: high efficiency steam traps, condensate pumps and vacuum pumps.
- Installation of distributed control system (DCS).
- Capacitor banks for power factor improvement

For the participating industrial customers, DSM pilot programme, succeeded to demonstrate the high savings potential that could be achieved by implementing low cost measures identified during the facility audits. However, no remarkable success had achieved in monitoring and verification of the implemented DSM measures, due the lack of customer information and supply of supporting services as well as the due time of ECEP activities.

According to a draft report on the replicability of ECEP technologies, the national market potential could be as large as 4.0 million tones oil equivalent (TOE) in annual energy savings at an investment cost of nearly US$ 2.9 billion[27].

On the other hand, ECEP, including the jointly implemented DSM pilot programme in Alexandria, addressed several market and institutional barriers that limit the rate of adoption of energy-efficient technologies and practices in Egypt. Most important barriers are: low consumer awareness, misplaced perceptions of technology risk, poor maintenance practices, and under-developed service infrastructure. Other barriers, such as energy pricing and public sector practices, are being addressed in continued tariff reforms and preparations for continued privatization of public sector enterprises. The need to address all market and institutional barriers in a comprehensive and coordinated strategy, however, remains a high priority. Achievement of the potential economic, environmental, and employment benefits of increased efficiency will be stalled until the barriers are addressed and a strategy that leads to a sustainable market of energy services is put in motion.

Figure 2.4 Phased Approaches to DSM in Egypt



<u>Source:</u> **ECEP DSM Report, Energy Conservation and Environment Project, Cairo, 1998**

2.4.6 Lessons *Learned*

The key lessons learned from the wide DSM experience in USA and many countries are summarized below:

- DSM often has a low overall impact in its early phase of implementation, but this can expand quite rapidly once lessons are absorbed and pilot programmes expanded and replicated.
- The design of DSM programmes should be based on local context. It may be more useful to limit outside expertise to discrete assignments and training activities, leaving the local utility staff (as in the case of Thailand) to design the programmes based on market research conducted and strategies developed in-house.
- Clear definition of DSM programme objectives. An important lesson is that DSM objectives should be clearly defined up front and have long-term in addition to short-term objectives, to help maintain continuity in operation. These objectives should address such issues as: public purpose or commercial; load management or energy conservation; economic/ environmental benefits or financial gains; sector priorities, etc. The priorities identified will drive how programmes develop.
- The design phase of DSM programme should consider a range of intervention strategies and assess the cost-effectiveness of each option. There should be also a functional process for feeding evaluation results back into programme design and make relevant adjustments.
- TV and newspaper advertisement increased the awareness and created a demand-pull for CFLs.
- Development and promotion of national labelling and standards for CFLs helps customers to identify high quality CFLs and importers to minimize imports of lower quality CFLs.
- Subsidizing the price of CFLs and distribution to few retailers distorts the market.
- Taxes and duty on imported CFLs must be reduced to make CFLs more prices competitive with incandescent lamps.

- Utility – sponsored warranty and branding may help to remove the barrier for promoting CFLs and influence the trust in technology.
- The experience of Thailand and Egypt demonstrates the importance of implementing programmes using the phased approach, although this could have been further strengthened by timely evaluation and programme redesign. It is preferable to implement pilot initiatives, and then evaluate and refine them before expanding and scaling-up implementation effort.
- Consumers should commit some resources before they get subsidies. The experience of Thailand and USA indicates this as a better design than 'all free' schemes as in some other countries.
- It should be a priority to initiate DSM capabilities and produce momentum, rather than keep debating on how best to achieve results.
- Evaluation should be an integral part of DSM plans and must be made concurrently. The evaluation should also be dynamic so as to give regular feedback on programme effectiveness and allow for on-going adjustment.

Concerted efforts by power companies with the regulatory commissions are crucial to achieve substantial energy savings and efficiency improvement potential.

2.5 DSM Activities in Kuwait: Literature Review

Despite the high rate of growth in electricity consumption in Kuwait, DSM has not yet been considered as a policy option meanwhile, a modest attention is given to promote energy conservation measures.

Due to the climatic conditions in Kuwait, and heavy use of air conditioning (AC) systems in summer, most of the studies and researches are focused on efficiency improvement and optimum performance of AC systems. The leading organization, in this field is the "Kuwait Institute for Scientific Research (KISR)", having a long experience in energy efficiency improvement and efficient buildings.

Research studies on energy efficiency and energy conservation by KISR and the Kuwait University in the 80's included the following:

- Effect of building standards on peak cooling load, including building material, window types, shape and colour.

- Energy saving effect of different air conditioning systems, such as solar cooling and cool-storage assisted systems.
- Energy saving effect of automatic air conditioner and light control.

As a result of the combined effort between the MEW and KISR, the Energy Conservation Code, called the "Code of Practice" was developed during the early 80's. The Code of Practice defines basic standards concerning peak load for residential and commercial buildings, shops, supermarkets and institutional buildings. In order to meet these standards, certain minimum requirements for energy conservation have to be met for wall and roof insulation, glazing, ventilation, air filtration control, AC system performance, etc. Specifically, the building codes make it mandatory for construction to have wall and roof insulation, use reasonable glass area and avoid dark colours for external walls and roofing, in order to limit the cooling load requirements.

After the code was enforced and implemented for a number of years, MEW and KISR agreed to pursue a comprehensive research programme to update and revise the existing code. Meanwhile, KISR is working, since the early 90's, on a project for the "Advancement of Energy Conservation Standards and Practical Measures for their Implementation in Kuwait".

Some efforts have also been made by the staff of KISR to explore the opportunity of promoting the utilization of CFLs[10]. However it needs more effort and involvement of different parties such utility, manufacturers and customers.

2.6 Summary

DSM is the planning and implementation of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape – i.e. in the time pattern and magnitude of a utility's load. Utility programmes falling under the umbrella of the DSM include load management, new uses, strategic conservation, electrification, customer generation, and adjustment in market share.

The new planning and policy context in which DSM and energy efficiency initiatives have been most effectively implemented is called "Integrated Resource Planning (IRP). IRP is a long-term planning process that allows electric utilities to compare consistently the cost-effectiveness of all resource alternatives on both the demand and supply side, taking into account their different financial, environmental and reliability characteristics. IRP and DSM can help ease electricity supply problems in Kuwait and other developing countries. The sooner these processes are begun, the sooner these countries will start reaping the benefits.

In Kuwait, most of the efforts done during the last two decades are focused on energy efficiency improvement and optimum operating techniques for AC systems in commercial and governmental buildings. Other DSM measures, such as the use of cool storage systems for peak load reduction and high efficiency lighting were also analyzed in some studies. Almost all energy audits and studies are conducted by the Kuwait Institute for Scientific Research (KISR).

To promote wider techniques of DSM, still a lot of work has to be done, particularly in the residential sector that consumes around 65 percent of the total electricity consumption.

If the Code of Practice and regulations are strictly applied, and an efficient monitoring system is implemented, then the energy balance of new buildings could be improved.

CHAPTER 3

DEMAND ANALYSIS AND FORECAST

3.1 OVERVIEW OF ELECTRICITY DEMAND IN KUWAIT

The State of Kuwait has a well-established electricity sector owned and operated by the Ministry of Electricity and Water (MEW), through the Department of Electricity, the only Kuwait's utility. The power sector has been able to satisfy the highly increased growth in electricity consumption, easily by adding new generation capacity. The department of electricity in MEW is a vertically integrated generation, transmission and distribution utility that sells power directly to the customers.

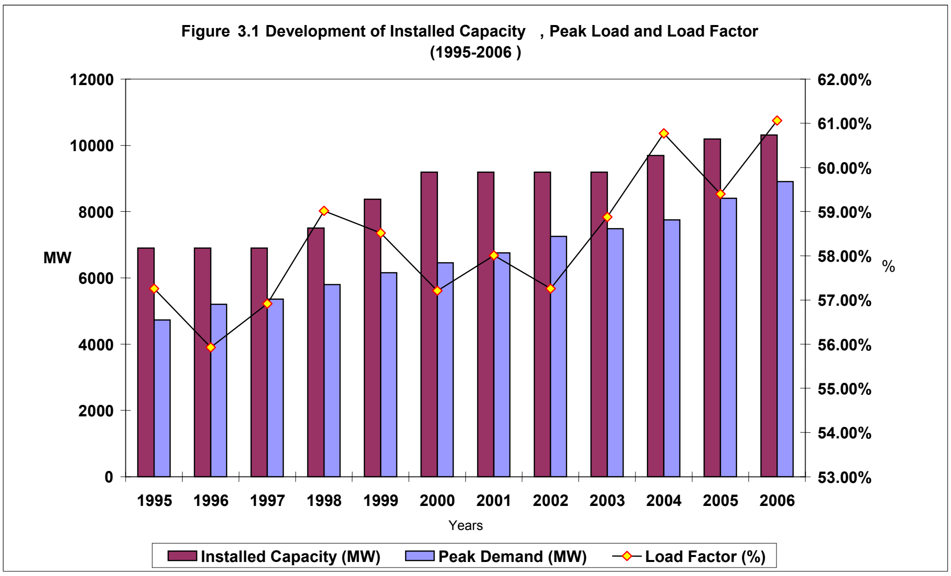
a) Installed Capacity and Peak Load

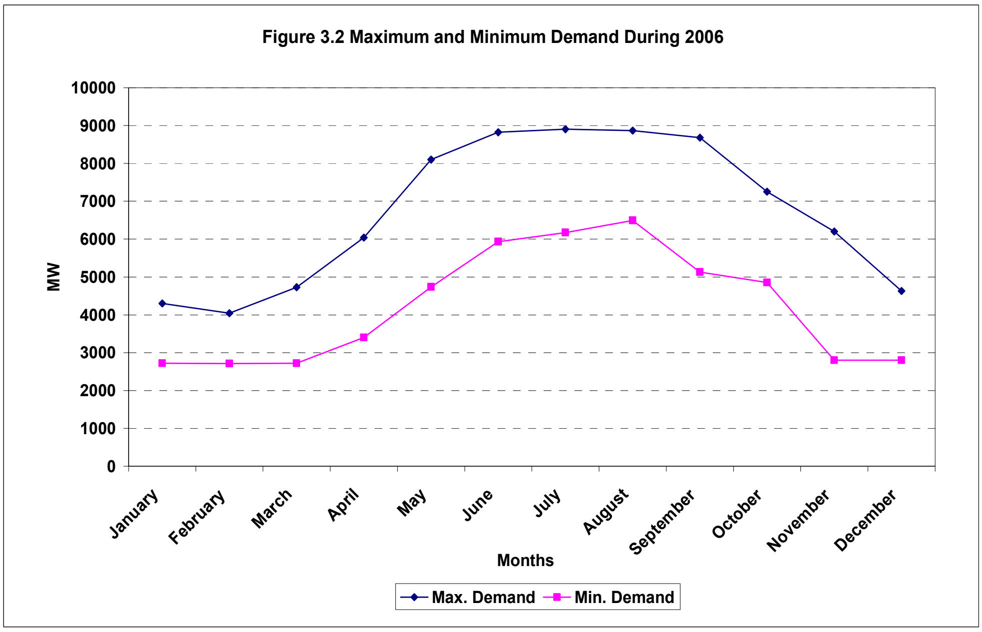
The installed capacity in Kuwait was 6,898 MW in 1995, increased to 10,313 MW in the 2006[11]. This capacity is generated by five power plants (Shuaiba, Doha East, Doha West, Az-Zour South and Sabiya), with steam turbines representing about 90 percent, and gas turbines the rest. Gas turbines are used, mainly, to support peak load. Most power plants are integrated with water desalination.

The peak load increased from 4730 MW, in 1995, to 8900 MW in 2006, with an average annual growth rate approximately 5.9 percent. During the last decade, the percentage of peak load to installed capacity has been increased from 68.6% to 82.5%. Demand for power is twice as high in the summer as in the winter because of air-conditioning. This condition puts stress on the system, requiring large amounts of reserve capacity.

Figure 3.1 shows the development of installed capacity, peak load and annual load factor, during the period 1995-2006.

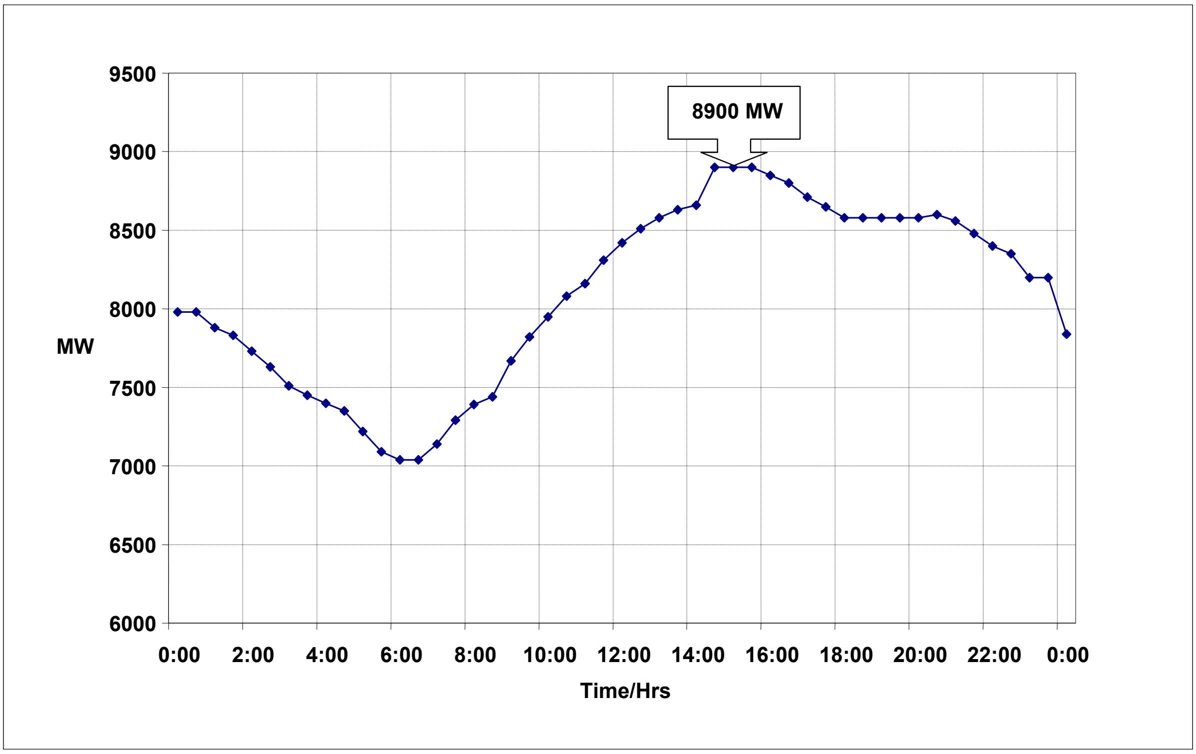
The monthly peak demand and minimum (base) load occurred in 2006 are shown in Figure 3.2. In 2006, the recorded peak demand (8900 MW) occurred in July. The peak load follows, to some extent, the monthly maximum temperature.





The daily load curve on July 26, 2006, during which the summer maximum demand occurred is illustrated in Figure 3.3. At this day, the maximum temperature and maximum humidity were 49°C and 6% respectively. As shown in the figure, the maximum demand is relatively flat, with loads very close to the daily peak for several hours, indicating the constant effect of air-conditioning load during the warmest portion of the day.

Figure 3.3 the Peak Load Profile on July 26, 2006

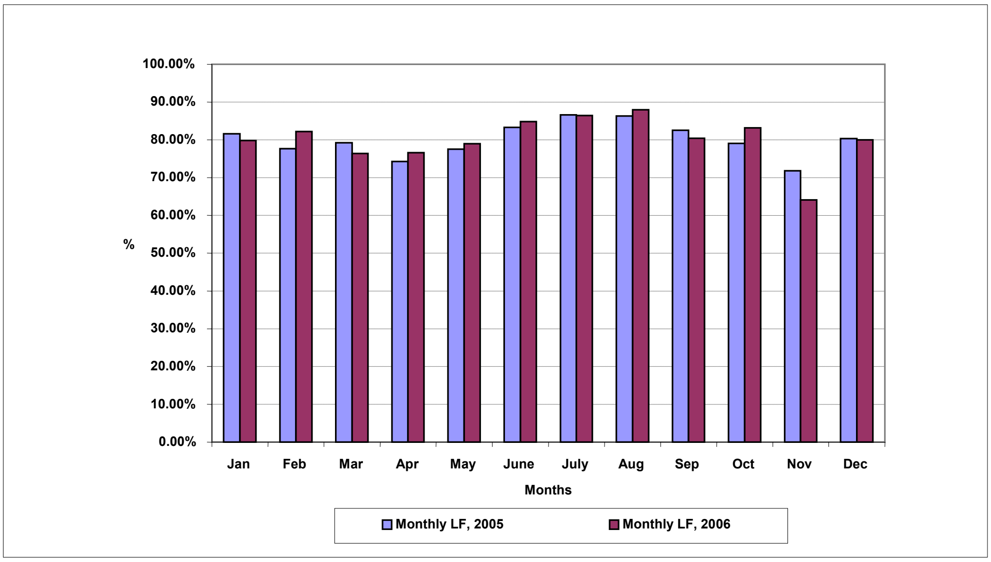


b) Load Factor

The development of annual LF for the period 1995 – 2006 is shown in Figure 3.1. Due to the seasonal variation in peak demand, the annual load factor is relatively low and ranges from 55.8% to 62.0% with an average value 58.5%.

The outside air temperature plays also an important role in electricity monthly demand variation. The monthly load factor for 2005 and 2006 is illustrated in Figure 3.4. It ranges between 77.6 and 81.6 % in winter and between 82.5 and 86.6% in summer.

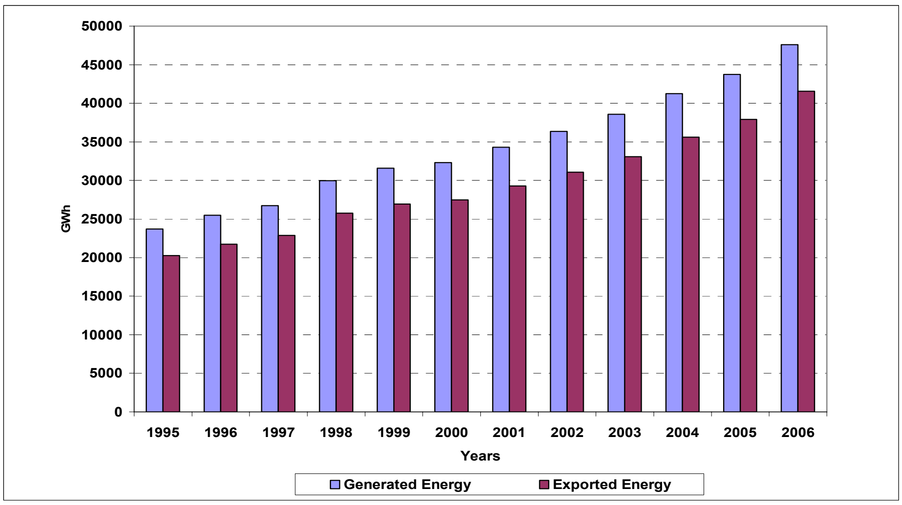
Figure 3.4 Monthly Load Factor for 2005 & 2006



c) Generated and Exported Energy

In 1995 the gross energy generated by the five power plants in Kuwait was 23724 GWh, increased to 47605 GWh in 2006, with an average growth rate 6.5%. The development of the gross generation during this period is shown in Figure 3.5. The net energy generated, or exported to the grid (sent out) is also shown on the curve. The difference between gross energy generated and exported to the grid is the auxiliary consumption of the power plants including energy used for desalination. In 2005, the energy exported was 41570 GWh and the energy consumed by power plants for both auxiliary systems and desalination is 6035 GWh representing 12.8% of the gross energy generated.

Figure 3.5 The Development of generated and Exported Energy



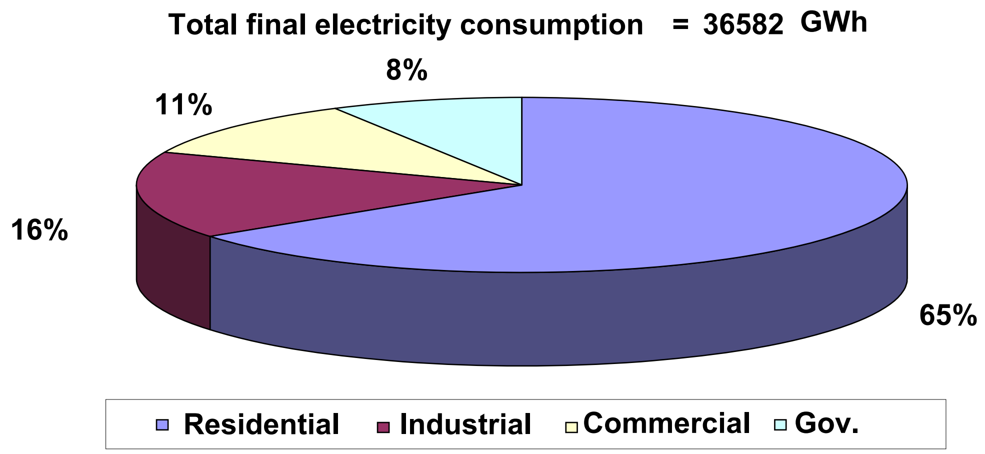
d) Final Energy Consumption and Distribution by Sectors

Data on the final energy consumption and its distribution among sectors are not available. The final energy consumption will be estimated by deducting the transmission and distribution (T & D) losses from the exported energy. Figures on T & D losses are not published by MEW in its latest reports. However, The Statistical Year Book of 1986, states that the T & D losses have been around 11 to 13 percent of the exported energy during 1972-1982. Thus an average of 12% will be assumed for the T & D losses.

A typical distribution of electricity consumption by sector is shown in Figure 3.6. It is clear that the residential sector is the major consumer of electricity sharing 65% of the total energy consumption, followed by industrial sector (16%), government sector (11%) and commercial sector (8%). The amount of electricity consumed by all sectors is shown in the figure for 2006.

MEW estimates, that a high portion of the total energy consumption is used for cooling purposes (the use of AC systems), amounting about 60%.

Figure 3.6 the Distribution of Final Electricity Consumption by Sector



3.2 Residential Sector in Kuwait

a) Population and Households

The growth of demand in the residential sector is closely tied to the growth of population. According to the latest 1995 census[28], the total population of Kuwait has reached 1,575,570 persons.

According to the UN Department of Economic and Social Affairs/Population Division, the total population of Kuwait reached 2.687 million persons in 2005, and the average growth rate during the period 2000 – 2005 was 3.7%.

Kuwaiti national population is projected to increase at an average growth rate as shown in Table 3.1.

Table 3.1 - Projected Rate of Growth of the Kuwaiti Population

Period	Rate of Growth
2001 – 2010	2.7%
2010 – 2020	2.2%

Source: ILO/TF/Kuwait/TN1, May, 2005.

Dwellings in Kuwait are usually classified into two categories: private or collective (public sector). Based on the preliminary 2005 census, the total number of households is 330,624 divided into 307,282 private and 23,342 collective households. The private Kuwaiti households accounted 129,541 and the number of non-Kuwaiti households was 177,744. A typical Kuwaiti household might consist of seven persons: The parents, three children and two expatriate maids. The structure of the households of non-Kuwaitis differs from those of local population. Most of the expatriates are living without their families in Kuwait. In most cases, they are occupying one dwelling with several parties. Table 3.2 shows the development of households according to the 1985, 1995 and 2005 censuses.

Table 3.2 Development of Households (1985-2005)

Households	1985	1995	2005	Percentage Increase (%)	
				1985-1995	1995-2005
Private	227201	237937	307282	4.7	29.1
Collective	9772	17540	23342	79.5	33.1
Total	**236973**	**255477**	**330624**	**7.8**	**29.4**

Source: Ministry Of Planning, Statistical Review, www.kuwait-info.com

b) Housing Characteristics and Stock

The government through the Public Authority for Housing Welfare (PAHW) is major provider for the residential buildings. Residential buildings in Kuwait are usually classified by type as: Apartment building, villa, traditional home or others. According to the Public Authority for Civil Information (PACI), the stock of residential buildings by type is available only for the two censuses years 1985 and 1995. However, estimates for the stock for the base year 2005 were made as shown in Table 3.3.

Kind and size of household or dwellings in Kuwait determines to a large extent residential electricity demand. The total stock of buildings in Kuwait is estimated at approximately 237,000 conventional residential dwellings.

The estimates conducted by a German consulting office "Lahmeyer International GmbH – The association of Engineering Partnership" in 1999, showed that dwelling stock consists roughly of:

- *122,666 apartments (52%),*
- *52,234 villas (22%)*
- *30,450 traditional homes (13%)*
- *31,664 other dwellings (13%) – other dwellings are mostly low-income dwellings.*

As shown in Table 3.3, the share of villas to the total dwelling stock reached more than 60% in 2005.

Table 3.3 Types and Numbers of Dwellings[29]

Building	Years			Increase 1985-1995 (%)	Increase 1995-2005 (%)
	1985	1995	2005		
A- Dwellings Stock:					
Private	219042	234153	303045 (982.26%)	6.9	29.4
Collective	9801	17529	23354 (6.34%)	78.8	33.2
Vacant	33356	32763	35762 (9.71%)	- 1.8	9.2
Under Construction	6921	3129	6235 (1.69%)	- 54.8	99.3
Total	269120	287574	368396 (100%)	6.9	28.1
B- Type of Dwellings:					
Apartment	9959	9862	13579	- 0.1	37.7
Villa	53839	61870	104650	1.4	69.2
Traditional Home	33670	30969	31000	- 0.8	0
Others (*)	18661	17155	15800	- 0.8	- 0.8
Total	116129	119856			

Source: Ministry Of Planning, Census and Statistical Sector, www.kuwait-info.com
(*) Others include temporary buildings, chalets, buildings under construction, etc.

In reality, more than 50% of the Kuwaiti prefers to live in villas, while about 35% are living in traditional homes and only 15% are living in apartments.

Based on the data from the construction statistics[30], the area of new villa ranges between 500 and 900 m2, and the area of new apartments lie in the range of 150 to 180 m2.

Table 3.4 shows the classification of residential consumers according to ranges of consumption in both private and apartment buildings as published in 1999. Approximately half of the residential consumers in private dwellings (320,890 connections in 2005) consume less than 4000 kWh per month.

Table 3.4 Electricity Consumption of Residential Consumers[31]

Private Houses			Apartment Buildings		
Consumption (kWh/month)	**Share in Number (%)**	**Share in Consumption (%)**	**Consumption (kWh/month)**	**Share in Number (%)**	**Share in Consumption (%)**
1 – 4000	49	22	1 – 1250	45	18
4001 – 6000	21	20	1250 – 2500	42	46
6001 – 9000	18	26	2501 – 4200	9	17
> 9000	12	32	4201 – 6250	2	5
			> 6250	2	13
Total	**100**	**100**		**100**	**100**

Source: Al-Qabas (Local Official Newspaper), Kuwait, 12 August, 1999.

c) Electricity Tariff

Almost all consumers in Kuwait, including residential sector, are charged a flat rate of 2 fils (≈ US¢ 0.6) per kWh of electricity, when in fact, the cost of producing each kWh has been estimated at 14 to 26 fils, which means that electricity is subsidized by 12 up to 24 fils per kWh.

During the last two decades, several proposals were made by MEW for tariff increase however; the tariff modification was not implemented.

3.3 Energy Consumption by End-use Equipment

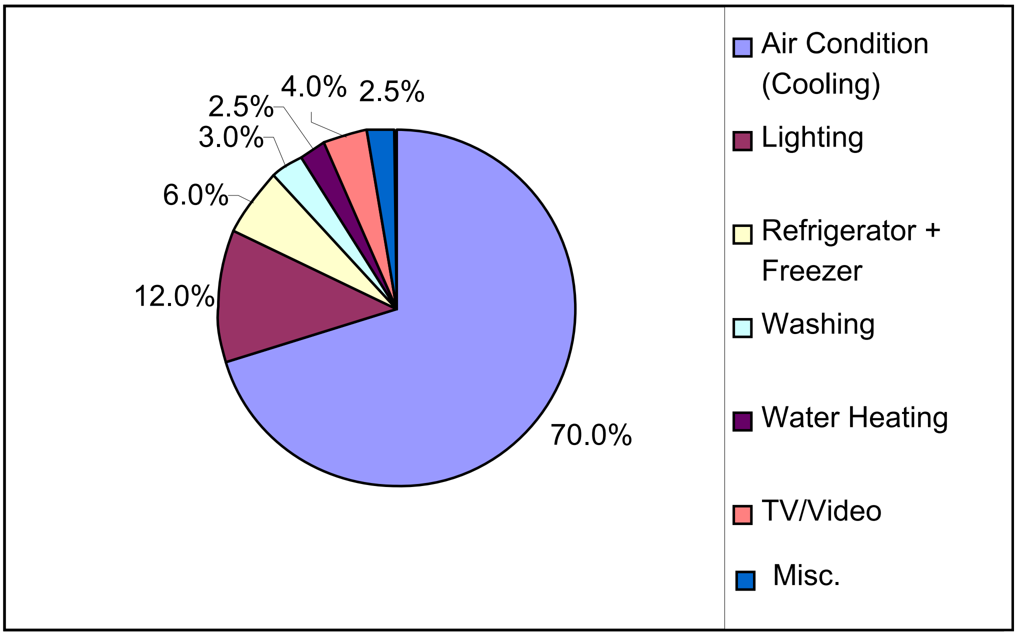
For successful implementation of DSM measures in the residential sector, it is important to explore the hourly power consumption of electrical end-use appliances on typical winter and summer days. Unfortunately, exact data for the electricity consumption by end-use equipment is not available. According to the World Bank study conducted in 1993, air conditioning systems accounted for 73% of the residential consumption in 1989, and thus, that is equivalent to, at least, 47% (73% * 65%) of total final energy consumption (not counting the air conditioning load of other consumer categories). This estimate is consistent with the recent data, provided by MEW, pointing out that summer peak is almost double winter peak due to the load required for AC.

Assuming the same share of AC consumption in the residential sector is still valid for the present time, thus the amount of electrical energy used by AC equipment in the whole sector is estimated as 17358 GWh.

Lighting comes in the second place, after AC, with respect to energy consumption, since most of the Kuwaitis use chandeliers in their homes lighted with as much as 12 to 24 lamps. The type of lamps used is most likely incandescent 40 or 60 Watt. The compact fluorescent lamps (CFLs) are not yet widespread in Kuwait.

Roughly, the breakdown of the electricity consumption by type of end-use equipment could be estimated as shown in the pie chart below (Figure 3.7).

Figure 3.7 Electricity Consumption by Type of End-Use



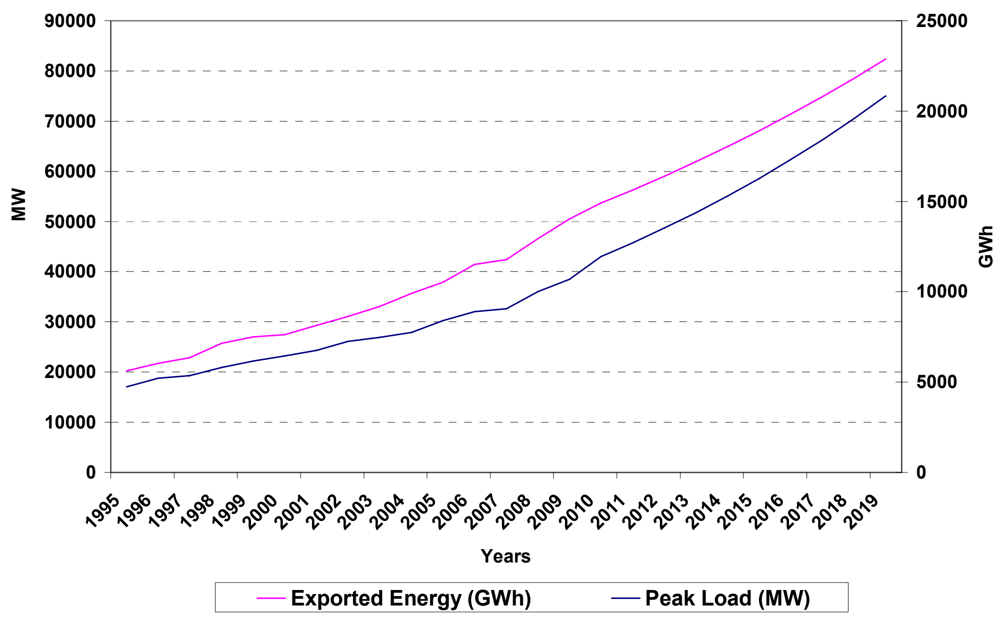
3.4 Baseline Scenario and Demand Forecast

To determine the DSM potential for the residential sector, it is important to establish a disaggregated base-line demand scenario of energy consumption and demand forecasts. Currently, there are no publicly available energy consumption forecasts that include end-use sector (residential, industrial and commercial) breakdowns.

According to the latest MEW- 2007 statistical year book, the future estimates of installed capacity, peak load, and generated energy are provided for the years 2007 to 2011. The peak load is expected to grow at an average rate of 11.9% to reach 14250 MW in 2011 (MEW Statistical Y. Book, P93). This growth rate is extremely high; and as a conservative approach we will consider the average growth rate from 1995 to 2010, which is approximately 6.37%. With this rate the baseline peak demand forecast will be extended to the end of 2019 as shown in Figure 3.8. The peak load is expected to reach 18 GW by the end of forecast period.

The generated and exported energy will grow, almost at the same growth rate of 6.5% and are expected to reach 108947 and 82,388 GWh respectively at the end of 2019. Figure 3.8 shows also a plot of baseline forecast for the exported (sent out) energy from 2005 to 2019 inclusive.

Figure 3.8 Baseline Demand Forecast



3.5 Summary

The installed capacity in Kuwait reached 10,313 MW by the end of 2006, and the peak demand during the same year reached 8,900 MW. Due to the seasonal variation in peak demand, the annual load factor is relatively low and ranges from 55.8% to 62.0% with an average value 58.5%.

The gross energy generated in Kuwait in 2006 reached 47,605 GWh, with an average growth rate 6.5% during the last decade. Around 13.3% of this energy is used for desalination and auxiliary power and the rest is exported (sent out) to the grid.

During 2006, the final energy consumption was estimated at approximately 36,582 GWh, equivalent to the exported energy minus the transmission and distribution losses (about 12%). The distribution of final energy consumption among sectors is estimated at: 65% for residential sector, 16% industrial, 11% commercial and 8% Government sector.

The residential sector is dominant in energy consumption due to the heavy use of air conditioning systems in summer.

According to the latest 1995 census, the total population of Kuwait was estimated at 1,575,570 persons, from which the Kuwaitis population is 653,616 persons representing estimated population of Kuwait reached 2.687 million persons.

The data of 2005 census indicated that the number of households in Kuwait reached 330,624 divided into 307,282 private and 23,342 collective households. Residential buildings are usually classified into three categories: apartments, villas and traditional buildings. The type of building defines, to large extend, electricity demand; 49% of private houses consume less than 4000 kWh/month, about 40% consume from 4000 to 9000 kWh/month, and 12% consume more than 9000 kWh/month. The area of new villa ranges from 500 to 900 sq. meter, and the new apartment ranges from 150 to 180 sq. meters.

Almost all consumers in Kuwait, including residential sector, are charged flat rate of 2 fils (≈ US¢ 0.6) per kWh, with minimum subsidy 12 fils per kWh. This very low tariff is the main reason for the irrational use electrical energy.

Air conditioning systems are the major contributors of energy consumption in residential buildings, where they share about 70% of the total consumption. Rough estimates indicate that other end-use equipment in a typical Kuwaiti dwelling consume electrical energy as follows: lighting (12%), refrigerators (6%), and other end-use equipment (12%).

The peak load base-line demand forecast is expected to reach 20.8 GW by the end of 2019, while the exported energy is expected to reach 82,368 GWh. These values are important in evaluating the cumulative impacts of DSM programme(s).

Chapter 4

Energy Audits and Measurements

4.1 Introduction

This chapter includes the results of short audits (walk-through) and detailed audits as well as measurements conducted on selected types of dwellings. Our aim, by conducting these audits and measurements, is to identify the energy efficiency DSM options in the selected samples. The samples were selected to represent, as much as possible, the Kuwaiti residential sector behaviour. As mentioned earlier, the majority of Kuwaiti dwellings are classified into three types: private villas, apartments and traditional houses. Focusing on these types, we collected data for more than 50 villas, 50 apartments and about 20 traditional houses. The sources of data are mainly, the Ministry of Planning, Statistical and Information Sector, Kuwait Institute for Scientific Research (KISR), Ministry of Electricity and Water as well as site visits and a questionnaire designed for this purpose. A model of the questionnaire is shown in Appendix 4. Interviews with the owners helped in selecting the suitable dwellings for detailed energy audit and the possibility of conducting measurements.

By screening the available data, we selected 10 villas, 10 apartments and 5 traditional houses that could be suitable candidates for detailed audits, including measurements.

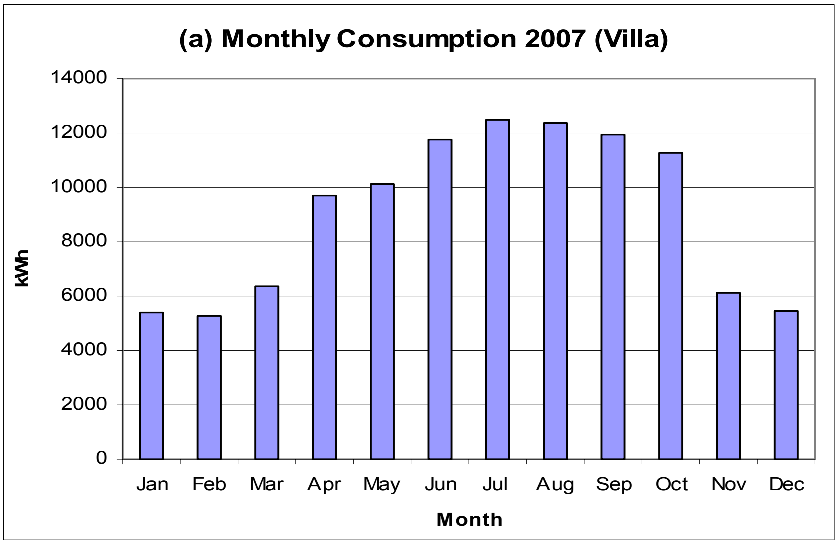
4.2 Results of Energy Audits

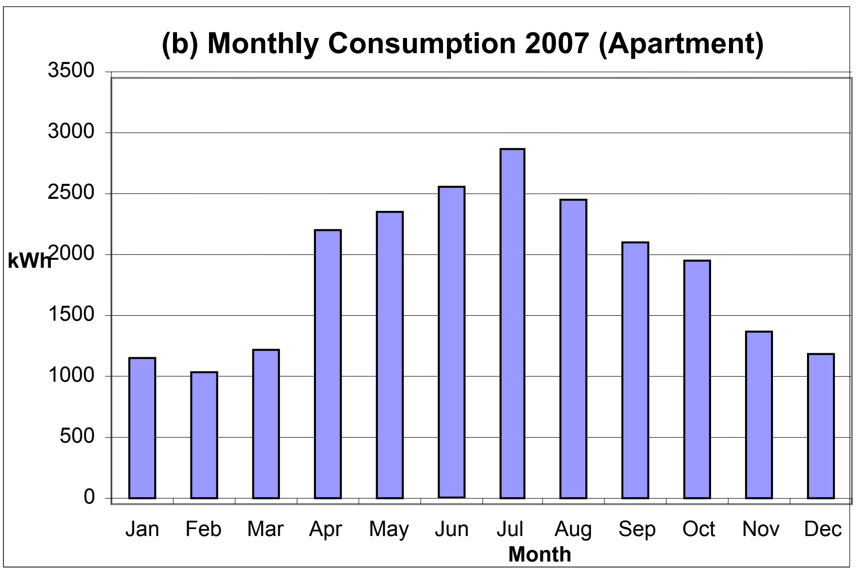
Through the energy, and in order to identify the DSM energy conservation opportunities (ECOs), it is important to identify where and how the building uses energy. For this purpose, we have to gather live information on the following:

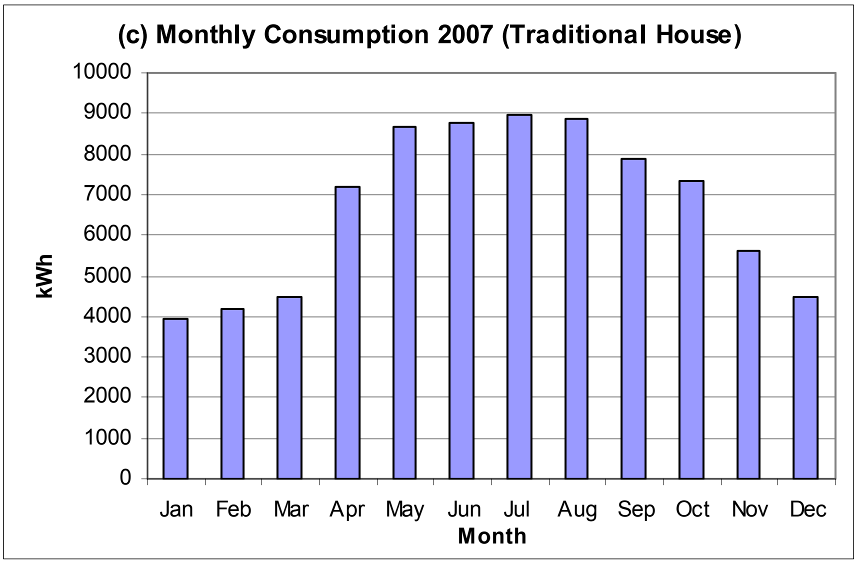
- Monthly energy bills.
- Building construction, including area, type of insulation, windows, etc.
- End-use equipment with particular emphasis on air conditioning (A/C) and lighting systems.
- Types, sizes, and, if possible, the average operating hours per day and/or week for home appliances such as washing machines, water heaters, TV, etc.
- Occupancy rates.

Unfortunately, the billing system in Kuwait is not accurate, meter checks do not take place on a routine basis and in many cases, the energy charge is paid in instalments, which not necessarily reflects the actual monthly consumption. However, with some billing adjustments, and meter readings for, at least, one week, it was possible to estimate the average monthly consumption. Based on the available billing information, the monthly consumption for three different dwellings (villa, apartment and traditional house) was estimated and graphed as shown in Figure 4.1 (a-c) for the year 2007. The average monthly consumption of winter season (from December to March), is 5613 kWh for the villa, 1145 kWh for the apartment, and 4280 kWh for the traditional house. These values represent approximately 52%, 51% and 54% of the summer (from April to November) average monthly consumption respectively.

Figure 4.1 – Monthly Consumption Based on Electricity Bills







During audits process, emphasis was made on four major contributors in energy consumption, specifically: building construction, air conditioning systems, lighting systems, and end-use equipment.

- **Building Construction:**

Assessment of building construction details, such as the type of wall and roof insulation was difficult, since the owner and/or occupants are not acquainted with such issues. However, most of the windows in the audited dwellings are double-glazed with low-e or reflective coated glass and either PVC or aluminium frames. Light coloured walls and roofs are common in, almost, all surveyed dwellings, however, the lack of shading is remarked in most of them.

- **Air Conditioning Systems:**

In most of the villas and traditional houses use air cooled packaged rooftop A/C systems. For villas the total installed cooling capacity ranges from 40 refrigeration ton (RT)[1] to about 60 RT depending on the size of the villa. Slightly less capacity is used in traditional houses. For apartments, split and window types are used. For the audited dwellings, most of the A/C systems are installed more than 10 years ago, characterized with low efficiency ranging 1.3 to 1.7 kW per ton, corresponding to an average coefficient of performance (COP) around 2.5. Proper sizing of A/C systems as well as energy performance will be investigated by simulation (Chapter 5).

[1] 1Refrigeration Ton = 3.516 kW

- **<u>Lighting Systems:</u>**

Most of the audited dwellings use incandescent lamps for lighting, either the 40 Watt thin type for chandeliers, or the 100 Watt type for normal space lighting. In rare cases, compact fluorescent lamps (CFL) are used; this assures the high potential of energy conservation in lighting by replacing the existing bulbs to CFL. Also used, with less extent, the 60 cm, 20 W and 120 cm, 40 W conventional fluorescent lamps; these types could be replaced by high efficiency fluorescent lamps 18 W and 36 W respectively.

- **<u>End-use Equipment:</u>**

A wide range of end-use equipment is used in Kuwaiti dwellings. It is, however, characterised by large sizes and high energy consumption. The operating hours of the end-use equipment, excluding air conditioning systems, were estimated based on interviews with occupants.

Table 4.1 shows an example of typical data gathered through energy audits, including the details of the four mentioned items.

Table 4.1 Typical Example of Audit Results

Parameter		**Villa**			**Apartment**			**Traditional House**		
A- Building Description:										
Orientation		North			North			East		
Land area (m^2)		500			---			600		
Construction area (m^2)		312			300			440		
Living (Serviced) area (m2)		294			245			290		
External Opaque wall area (m2)		364			216			540		
Total roof area (m2)		180			---			165		
Number of rooms		10			7			8		
Number of persons		7			5			9		
Windows		Double-glass 6 mm reflected coating, with 12 mm spacing and PVC frame			Double-glass 6 mm reflected coating, with 9 mm spacing, and PVC frame			Double-glass 6 mm film coating, with 9 mm spacing and aluminium frame		
B- Air Conditioning System										
Type		4 Packaged rooftop air cooled , total capacity: 45.83 RT, and EER 8.2			6 Split Units, Carrier of total cooling capacity 91980 kBtu/hr and average EER 9			2 Packaged rooftop air cooled of total capacity 42 RT, and EER 8.5		
C- Lighting	**Type**	Bulb	Bulb	Fluor.	Bulb	Bulb	CFL	Bulb	Bulb	Spot
	Watt	40	100	40	40	100	25	40	100	100
	Qty.	84	29	10	24	22	6	64	14	22
	Tot. Watt	3360	2900	400	960	2200	150	2560	1400	2200

D- End-use Equipment	**Type**	Refrigerators (2)	Refrigerators (1)	Refrigerators (2)
	Consumption	88 + 79 = 167 kWh/m	86 kWh/m	54 + 74 = 128 kWh/m
	Type	Clothes washer (2)	Clothes washer (1)	Clothes washer (2)
	Consumption	43 + 45 = 88 kWh/m	48.5 kWh/m	64 + 66 = 130 kWh/m
	Type	Water heaters (3)	Water heaters (2)	Water heaters (3)
	Consumption	1x540 + 2x270 = 1080 kWh/m	360 + 240 = 600 kWh/m	1x540 + 2x360 = 1260 kWh/m
	Type	TV (2)	TV (3)	TV (3)
	Consumption	Total: 223 kWh/m	Total: 82 kWh/m	Total: 72.6 kWh/m
	Type	Electric heaters (2)	Electric heaters (2)	Electric heaters (3)
	Consumption	Total: 270 kWh/m	Total: 240 kWh/m	Total: 360 kWh/m
	Type	Others (Computers, VCR, Radio, etc.)	Others (Computers, VCR, Radio, etc.)	Others (Computers, VCR, Radio, etc.)
	Consumption	Total: 369 kWh/m	Total: 64 kWh/m	Total: 130 kWh/m

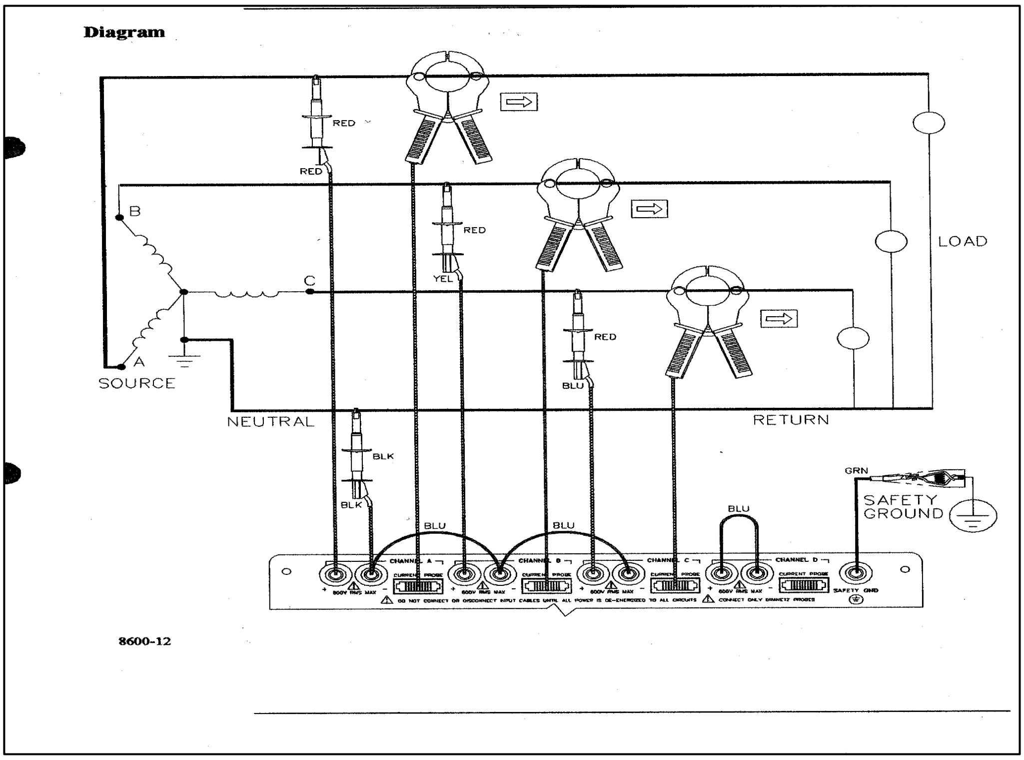
4.3 Results of Measurements

Measurements were carried out on samples of each of the dwellings type: a villa, apartment and a traditional house. To obtain a full picture on the energy demand and load profile, measurements were carried out using a demand analyzer: VIP – SYSTEM-3.

The instrument is connected in 4-wire mode as shown in Figure 4.2. It records on permanent basis the active and reactive powers, energy, power factor and harmonics. It also measures the true root mean square (RMS) of voltage and current and calculates the following parameters:

- Active power (kW)
- Reactive power (kVAR)
- Apparent power (kVA)
- True power factor (PF)
- Displacement power factor (dPF)
- Total harmonic distortion (THD) of voltage and current.

Figure 4.2 Three Phase 4-wires Connection Diagram



Measurements were carried for 10 villas, 10 apartments and 5 traditional houses of different consumption categories. Periods of measurements ranges from 3 to 7 days, including weekend in each period. Due to the high impact of weather conditions in Kuwait on energy use and the heavy use of air conditioning systems in summer measurements were carried out in winter (January 2008) when the air conditioners are off, and in summer (July 2008) when all air conditioning systems are in peak operation.

Measurements were carried out on the main feeders on the 380 V voltage level, supplying power to all loads in the dwelling. Figure 4.3 shows a typical electrical single line diagram (SLD), for an audited villa.

Figure 4.3 a typical Single Line Diagram of Electrical System (Villa)

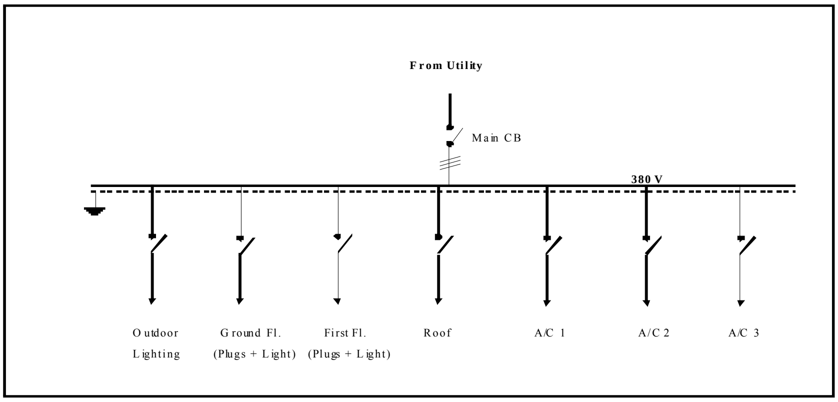


Figure 4.4 an Image of a Typical Villa in Kuwait

Figures 4.5, 4.6 and 4.7 show the daily power demand profile for a villa, apartment and traditional house respectively. The profiles are traced for both summer (July 2008) and winter (January 2008). The results of measurements conducted in 25 facilities are summarized in the following Tables.

Table 4.2 Summary of Measured Parameters

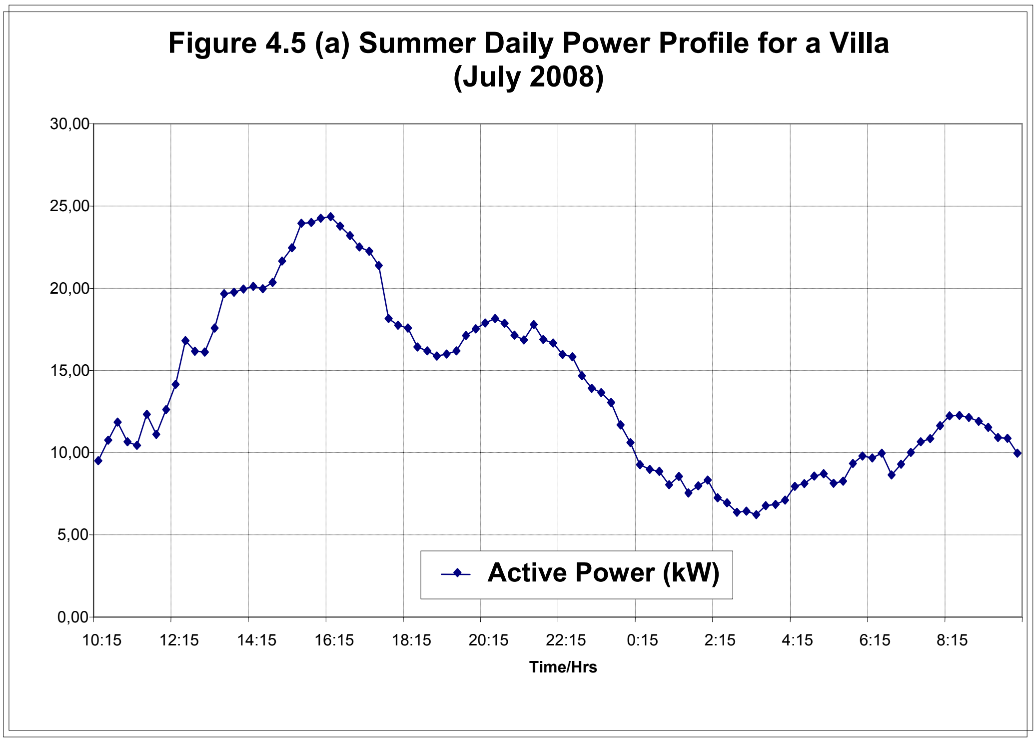
(a) For Villas		
Parameter	**Summer**	**Winter**
Maximum Active Power (kW)	18.2 – 34	10.5 – 17.2
Average Active Power (kW)	12.99 – 17.6	5.6 – 7.06
Average Reactive Power (kVAR)	9.4 – 12.74	3.62 – 4.0
Average Power Factor	0.79 – 0.84	0.79 – 0.9
Average Line Voltage (V)	389.6	390.8
Average Daily Consumption (kWh)	312 – 422	134 – 169

(b) For Apartments		
Parameter	**Summer (July)**	**Winter (January)**
Maximum Active Power (kW)	5.8 – 10.4	2.8 – 4.7
Average Active Power (kW)	2.71 – 4.31	1.08 – 1.56
Average Reactive Power (kVAR)	1.75 – 3.12	0.58 – 1.21
Average Power Factor	0.79 – 0.89	0.79 – 0.9
Average Line Voltage (V)	382	387
Average Daily Consumption (kWh)	65 – 103	26 – 37

(c) For Traditional Houses		
Parameter	**Summer (July)**	**Winter (January)**
Maximum Active Power (kW)	18 – 24	5.6 – 13.5
Average Active Power (kW)	11.08 – 13.33	3.72 – 4.72
Average Reactive Power (kVAR)	6.46 – 8.0	2.11 – 2.29
Average Power Factor	0.79 – 0.89	0.79 – 0.9
Average Line Voltage (V)	383.5	390
Average Daily Consumption (kWh)	266 – 320	89 – 113

The large difference between summer and winter consumption is clear due to the A/C cooling energy required. As indicated in Table 4.2, the ratio of average daily demand in winter (January) relative to that in summer (July) ranges approximately from 35% to 40%.

Measurements in almost all dwellings showed low power factor, this is due to air conditioners and fluorescent lamps as well as other electronic equipment. In Kuwait no penalty charge is applied for low power factor.



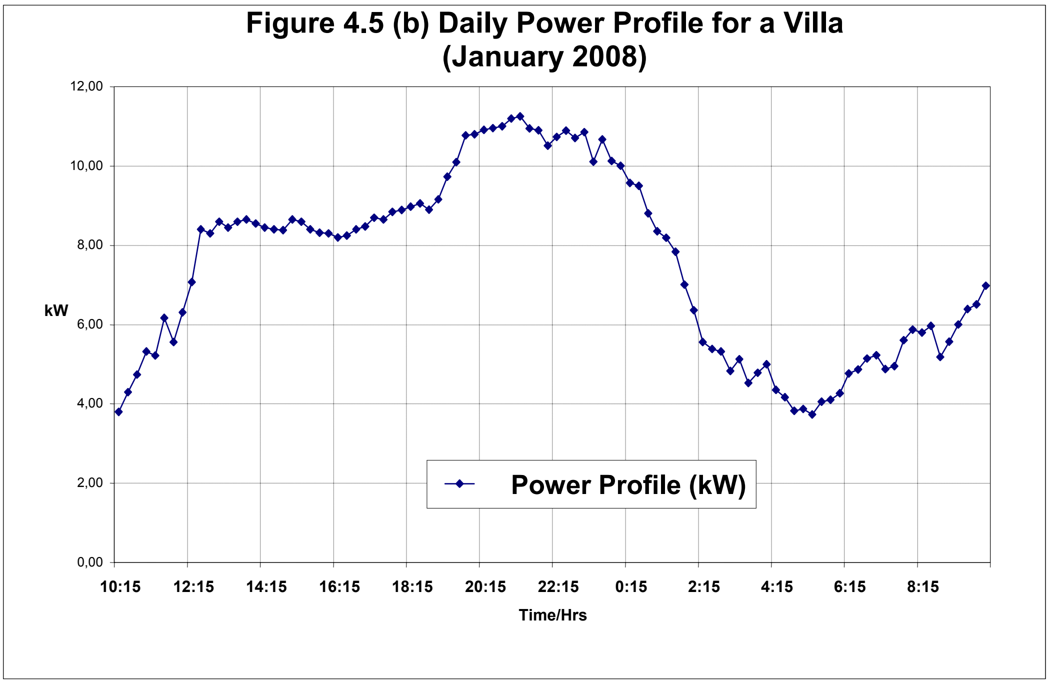


Figure 4.5 (b) Daily Power Profile for a Villa
(January 2008)
12,00
10,00
8,00
6,00
4,00
2,00
0,00
kW
Power Profile (kW)
10:15
12:15
14:15
16:15
18:15
20:15
22:15
0:15
2:15
4:15
6:15
8:15
Time/Hrs

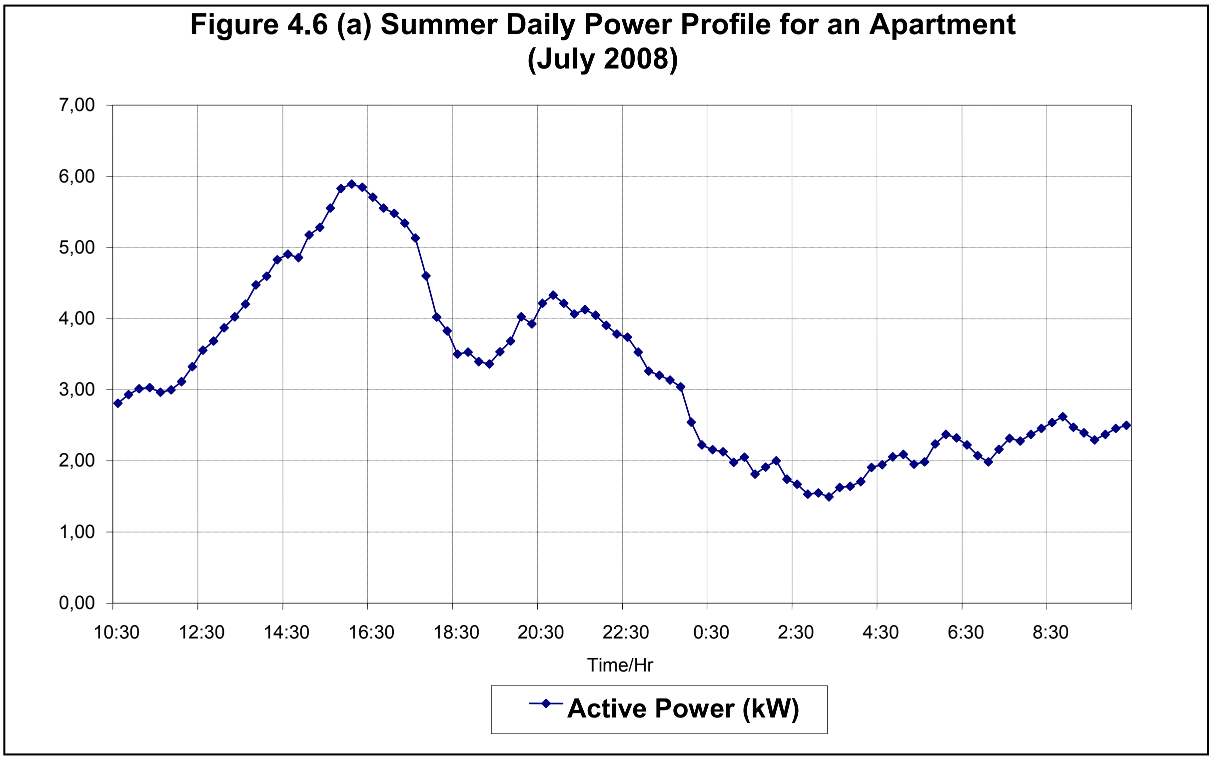


Figure 4.6 (a) Summer Daily Power Profile for an Apartment
(July 2008)
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
10:30
12:30
14:30
16:30
18:30
20:30
22:30
0:30
2:30
4:30
6:30
8:30
Time/Hr
Active Power (kW)

Figure 4.6 (b) Winter Daily Power Profile for an Apartment (January 2008)

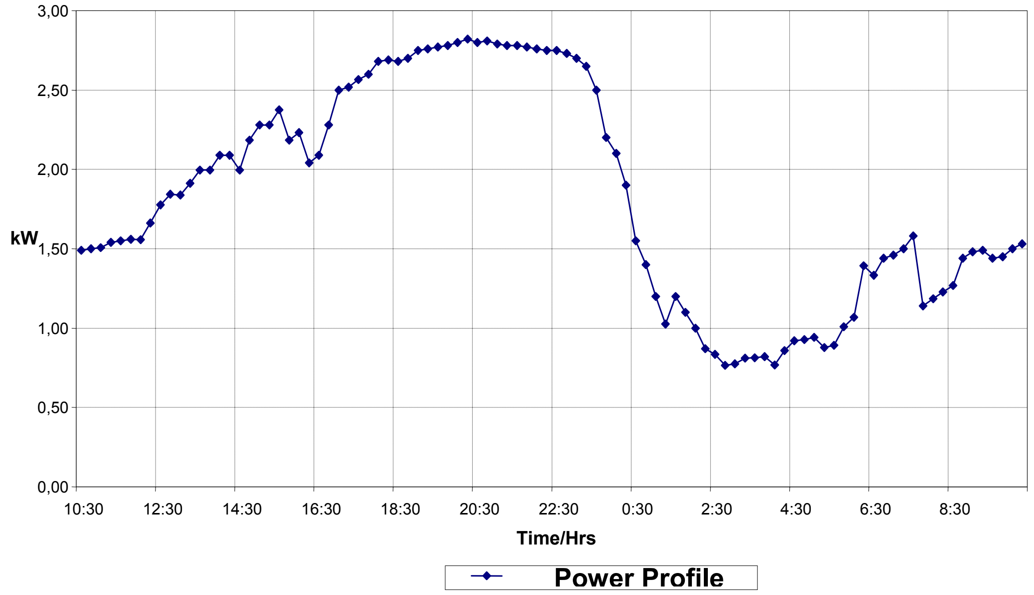


Figure 4.7 (a)- Summer Daily Power Profile for a Traditional House (July 2008)

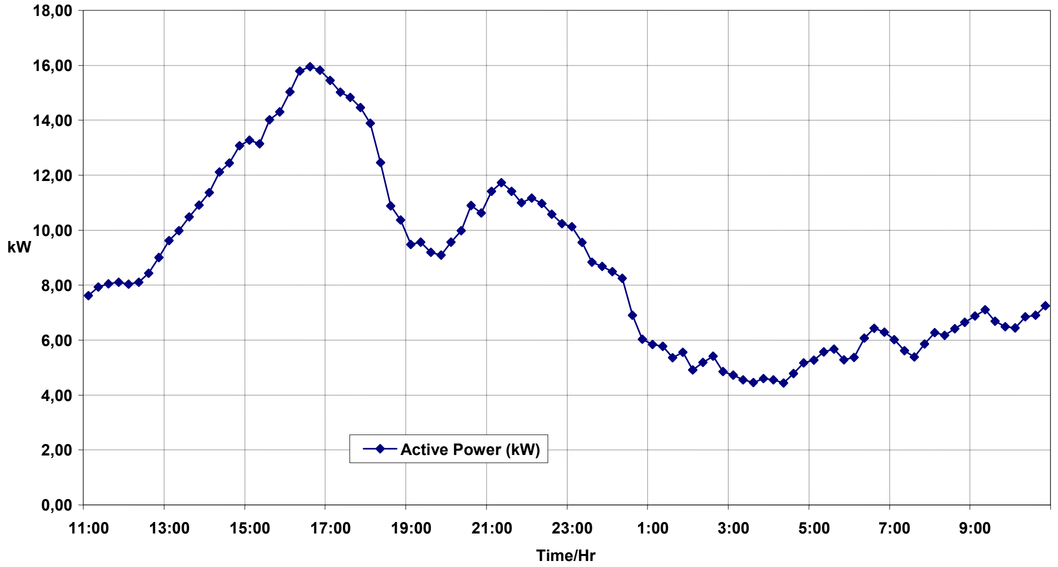
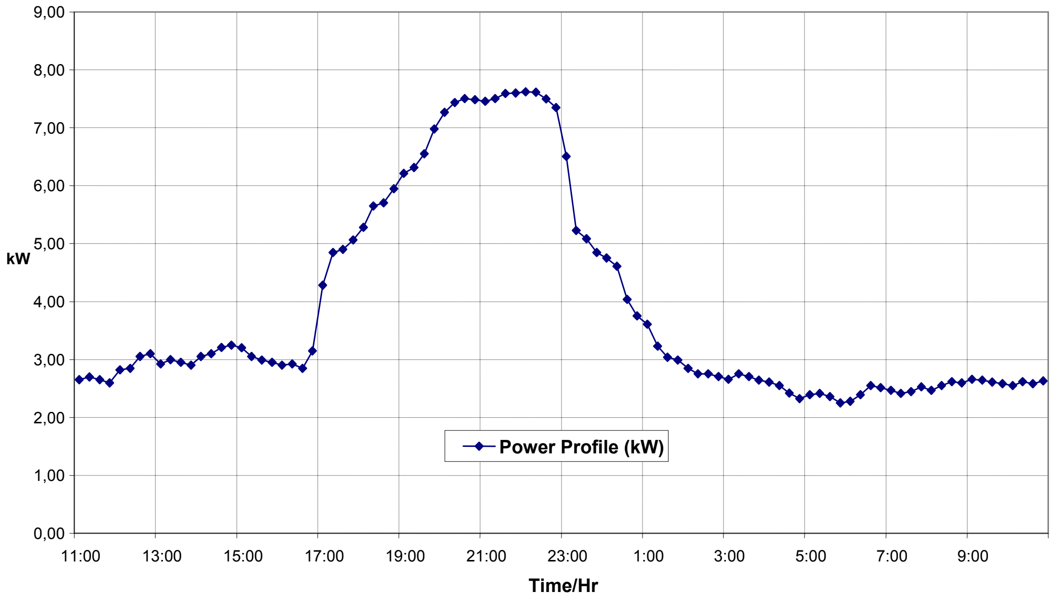


Figure 4.7 (b)- Winter Daily Power Profile for a Traditional House (January 2008)



4.4 Summary

Data collection and detailed energy audits conducted for 25 Kuwaiti dwellings (10 villas, 10 apartments and 5 traditional houses) during the first 8 months of year 2008 have revealed the following results:

- The average consumption, based on monthly bills and meter recordings, of the three types of dwellings is approximately:

	Winter	Summer
Villa (kWh/m):	5613	8870
Apartment (kWh/m):	1145	2250
Traditional house (kWh/m):	4280	7925

That is the average winter consumption almost half that of summer consumption.

- In data collection and walk-through audits, emphasis were made on the following main components:

a) Building construction,

b) Air conditioning systems,

c) Lighting systems, and

d) End-use equipment.

- Through energy audits, the main DSM options identified are:
  a) High efficiency lighting by replacing the existing fluorescent lamps to CFL.
  b) Measures related to air conditioning systems.
  c) Measures related to end-use equipment.

These measures, as well as others, will be investigated through building simulation.

- The results of measurements for, at least, three days for each facility (including weekend) have shown the following average electrical parameters:

	Villa	Apartment	Tr. House
- Average daily summer (July) demand (kW):	13-17.6	2.7-4.3	11-13.3
- Average daily winter (Jan.) demand (kW):	5.6-7	1.1-1.56	3.72-4.72
- Maximum daily summer (July) demand (kW):	18.2-34	5.8-10.4	18-24
- Maximum daily winter (Jan.) demand (kW):	10.5-17.2	2.8-4.7	5.6-13.5
- Average PF summer (July):	0.79-0.84	0.79-0.89	0.79-0.89
- Average PF winter (Jan.):	0.79-0.9	0.79-0.9	0.79-0.9

The ratio of average daily demand in peak winter (January) to the average daily demand in peak summer (July) ranges approximately from 35% to 40%. This, of course, is due to the high consumption of air conditioning systems.

CHAPTER 5

BUILDING SIMULATION

5.1 Introduction

In existing buildings, energy simulation is performed to analyze the energy performance of a building dynamically and to understand the relationship between the design parameters and energy use characteristics of the building.

From an energy point of view, a building is quite complex system. A particular measure taken for energy conservation might influence the building and the energy end-use of the building, as several measures might interact. This influence, and hence the real energy conservation, might be difficult to foresee without analyzing the effect of the measure taken on the energy end-use of the building in question as a whole. For example, replacing normal incandescent lamps to compact fluorescent lamps (CFLs) will have large effect on the air condition load, and hence on the overall energy savings. Therefore, assumptions about energy conservation gained by a particular DSM measure must include not only the conservation potential of the measure itself, but also its influence on the total need for energy when the building is in normal use. This is a fundamental prerequisite for achieving energy efficiency in reality.

Simulation process, including HAP, is performed sequentially in three programmes. The first programme (called SPACES or LOADS) uses weather data, user input regarding the characteristics of the building envelope, and the building's schedule of occupancy in order to calculate the heating addition and/or cooling extraction rates that occur in each building space. The energy performance of day-lighting, lighting, domestic hot water and other end-use equipment are also calculated in SPACES. The second programme (SYSTEM) uses the inputs of the first programme to calculate the demand for ventilation air, electricity, etc., to maintain temperature and humidity set points. In addition, control equipment, HVAC auxiliary equipment, and energy recovery equipment are also evaluated within the SYSTEM programme. The final programme (PLANT) simulates the behaviour of the primary HVAC system (boiler, chillers, cooling towers, etc.) in meeting these demands and predicts the fuel or electrical energy consumed.

5.2 Simulation Tool Used

The simulation programme used in research work is the Carriers Hourly Analysis Programme (HAP). It is mainly used in the design and analysis for commercial buildings; however, it is used successfully in residential applications. It has the advantage of better user interface and default features. The HAP estimates the annual energy consumption and energy costs for AC and non-AC energy consuming systems associated with a particular building design, by simulating its operation for each of the 8760 hours in a year. It calculates load requirement for the building for each hour depending on the difference between the internal and external gain/loss. Results of the energy analysis are used to compare the energy use and energy costs of the actual existing operation of the dwelling as it is (base-case) with the operation under alternative DSM measures. Specifically, HAP performs the following tasks during energy analysis:

- Simulates, on an hourly basis, the operation of all air conditioning systems in the building.
- Simulates, on an hourly basis, the operation of non – AC systems, including lighting and appliances.
- Uses results of the hour-by-hour simulations to calculate total annual energy use and energy costs.
- Generates tabular and graphical reports of hourly, daily, monthly and annual data.

All analysis work requires the same general five step procedure:

1) **Problem Definition:** First we have to define the scope and objectives of the energy analysis, including the type of building, type and rates of systems and equipment installed, and what alternate designs or energy conservation measures are being compared in the analysis.

2) **Gathering Data:** Before energy simulations can be run, information about the building, its environment, AC and non-AC equipment, and its energy prices must be gathered. This step required extracting data from building plans, evaluating building usage, studying AC system needs and acquiring utility rate schedules. Specific types of information needed include:
   - Hourly weather data for the building site: includes information on maximum and minimum temperature, humidity, seasonal variations, etc.
   - Building design parameters and description: includes information on construction material, type of walls, roof, insulation, windows, glazing and shading coefficients, infiltration, etc.
   - Internal load characteristics determined by levels and schedules for occupancy, lighting system, water heaters, office equipment, appliances and machinery within the building.
   - Data for AC equipment, controls and components to be used.
   - Data for non-AC energy consuming equipment.
   - Utility rate information for electric service used in the building (in our analysis, electricity is the only source of energy used).
3) **Entering Data into HAP:** It is very important to define input data parameters before using HAP, or any other simulation tool. Three building models from the audited dwellings were selected to perform the simulation: a villa, an apartment and a traditional house. The major components of energy simulation for each of these models are shown in Figure 5.1. As shown in the figure, climatic data and building construction details as well as end-use equipment are essential sources of information for simulation process. The output of the HAP is in the form of energy performance reports including energy consumption, costs, environmental emissions, etc.

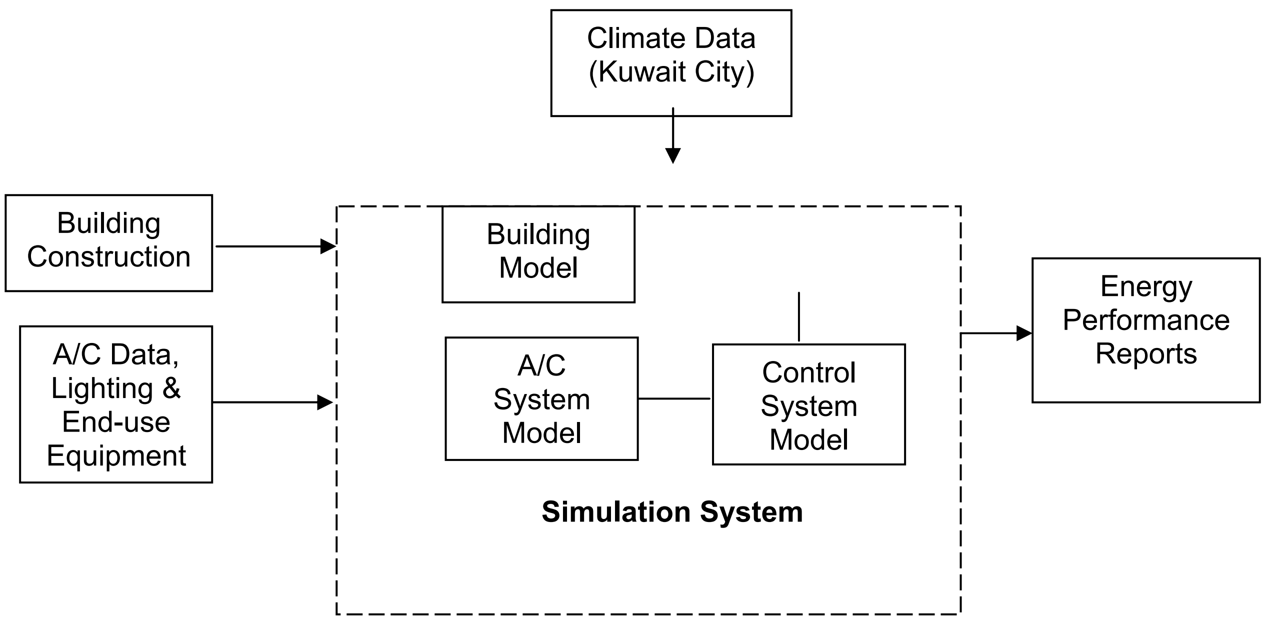
The data of the three dwellings description, air conditioning systems, lighting and end-use equipment are shown in Table 5.1. Data entry included the following types:

a. Weather data is entered by loading a simulation weather file from the library provided with the programme. For Kuwait city, the weather data is shown in Appendix 4.

b. Geometric data is entered, either for the whole building or divided into zones. All elements which affect heat flow in the space must be described, such as walls, windows, doors, roofs, skylight, floors occupants, lighting, electrical equipment, infiltration and partitions.
c. Air system data related to AC equipment used to provide cooling (in almost all Kuwaiti dwellings, AC is off during winter). An air system serves one or more zones. In our analysis, AC serves two zones (ground and first floors) for villa and traditional house and three zones for apartment (reception, master bed room and other bed rooms). The air systems typically used in the villas and traditional houses is the package rooftop units and in the apartments are split units of different ratings (see Table 4.1, Chapter 4).

d. Utility rate data is entered specifying the pricing rules for electrical energy. MEW charges a flat tariff rate of 2 Fils (≈ 0.006 US$) per kWh to almost all its residential consumers. MEW also states that the electricity production costs have been about 14 Fils (0.042 US$) per kWh delivered to the customer. Thus, the unit costs are 7 times higher than the average sales price. This means that the amount of subsidy is 12 Fils (≈ 0.036 US$) per kWh. The utility rate considered in this analysis is the minimum amount of subsidy, i.e. 12 fils (≈ US¢ 3.6) per kWh.

Figure 5.1 Major Components of Building Energy Analysis Simulation



5.3 Simulation Scenarios and DSM Measures

For each selected type of dwellings, the HAP simulation process included five DSM measures, in addition to, the base case. Table 5.1 (a) shows the input parameters for the base case and Table 5.1 (b) shows the variations in input data according to DSM selected option. Nine alternatives, including different DSM scenarios, were simulated as follows:

- **Alternative 1 - Base Case:**

Simulation is carried out for the base case scenario of each dwelling in its actual existing condition. Input parameters shown in Table 5.1 for the base case are based mainly on the results of detailed energy audits.

- **Alternative 2 - DSM1:**

In almost all audited dwellings, the thermostat setting was put in the range between 70 ^{o}F (21.1^{o}C) to 75 ^{o}F (23.9 ^{o}C). In this scenario, a simple DSM measure is applied by increasing thermostat setting from 75 ^{o} F (23.9 ^{o} C) to 78 ^{o} F (25.6 ^{o} C). Interviews with occupants have shown that the new thermostat setting is convenient in most cases.

- **Alternative 3 – DSM2:**

In this alternative, it is assumed that high efficiency lighting is used by replacing the existing incandescent lamps 40 W and 100 W to compact fluorescent lamps (CFL), of rated power 7 W and 25 W respectively. All other building parameters are kept the same as in the base case.

- **Alternative 4 – (DSM1 + DSM2):**

In this alternative, Simulation is carried out assuming that the two energy efficiency DSM options DSM1 and DSM2 are implemented simultaneously, the aggregated sum of savings is evaluated.

- **Alternative 5 – DSM3:**

Most of the existing air conditioning systems in the audited dwellings are not efficient with energy efficiency ratios (EER) ranging from 7.5 to 9.5. In this alternative, the simulation was carried out assuming that the A/C has been upgraded to a new type more efficient with EER about 11.0. In this DSM option, it is assumed that all other parameters are kept the same as in the base case.

- **Alternative 6 – (DSM1 + DSM2 + DSM3):**

In this alternative, it is assumed that all three previous DSM measures are applied simultaneously, and the accumulated energy savings are calculated.

- **Alternative 7 – DSM4:**

This DSM option is usually applied for new buildings. It takes into consideration the quality of roof and wall insulation. In this case, we assume that, the U-value of the base case roof insulation: 1.266 W/m^2K for villa, 0.613 W/m^2K for apartment, and 0.233 W/m^2K for traditional house has been increased to 0.363 W/m^2K, 0.392 W/m^2K, and 0.169 W/m^2K respectively. Moreover, the U-value of the base case wall insulation has been upgraded from 1.266 to 0.346 W/m^2K, from 0.613 to 0.392 W/m^2K, and from 0.233 to 0.169 W/m^2K for villa, apartment and traditional house respectively. Also, the medium colour of the villa's roof is assumed to be upgraded to light colour.

- **Alternative 8 – DSM5:**

In this alternative, it is assumed that part or all the end-use equipment (refrigerators, washing machines, water heaters, etc.) have been replaced by energy efficient ones. Assuming 25% increase in end-use equipment efficiency, with respect to the base case, simulation was carried out and the results are shown in the tables in appendix 9.

- **Alternative 9 – (Sum of DSM Options):**

This is the last alternative, in which it is assumed that all five DSM measures are implemented and the aggregate savings were calculated as shown in the tables of appendix 9.

Table 5.1 (a) Input Data For Building Simulation for the Base Case

Date:	**January 25, 2009**	**Dwelling Types:**	
Location:	**Kuwait City**	**Villa, Apartment and Tr. House**	
A. WEATHER DATA			
Latitude		29.2 Degree	
Elevation		180.0 ft	
Summer Design Dry Bulb Temp.		110.0 ºF	
Summer Coincident Wet Bulb Temp.		85.0 ºF	
Daily Temperature Range		25.0 ºF	
Winter Design Dry Bulb Temp.		45.0 ºF	
Atmospheric Clearance Number		1.0	
Data Source		Carrier Defaults	
Design Cooling Months		March to November	
B. GENERAL DWELLING DATA			
DATA	**VILLA**	**APARTMENT**	**TR. HOUSE**
Floor (Living) Area (sq ft)	3358	2637	3100
Building Weight (lb/sq ft)	90	120	90
Avg. Ceiling Height (ft)	10.2	9.0	9.0
Roof Gross Area (sq ft)	1722	1000	1700
C. LIGHTING DATA			
Power Density (PD)	1.1 W / sq ft	0.8 W / sq ft	0.8 W / sq ft
Fixture Type	Free hanging	Recessed (Unvented)	Free hanging
D. PEOPLE			
Occupancy (No. of persons)	7	4	7
Activity Level			
Zone 1	Sedentary Work	Seated at Rest	Seated at Rest
Zone 2	Sedentary Work	Seated at Rest	Seated at Rest
Zone 3		Seated at Rest	
E. AIR CONDITIONING INPUT DATA			
Equipment class	Packaged Rooftop Units	Split Air Handling Units	Packaged Rooftop Units
Air System Type	VAV	VAV	VAV
Number of Zones	2	3	2
Cooling T-stat (case 1)	$78\,^{0}$ F	$78\,^{0}$ F	$78\,^{0}$ F
Supply Air Flow	49978.4 CFM	6985 CFM	23000 CFM
Gross Cooling Capacity	550 MBH	153 MBH	500 MBH
Design OAT	$107\,^{0}$ F	$107\,^{0}$ F	$95\,^{0}$ F
Compressor & Fan Power	65 kW (8.5)	15.9 kW (9.6)	55 kW (9.1)

Table 5.1 (b) Modified Input Data For Building Simulation With DSM Options

	VILLA	APARTMENT	TR. HOUSE
A. WEATHER DATA			
The same as the base case			
B. DUILDING CONSTRUCTION			
1. Walls			
Gross Area (sq. ft)	1688	2143	2200
Absorbity	0.675	0.45	0.45
Overall U-value (Btu/hr.ft² º F)			
Base Case	0.223	0.068	0.06
DSM4	0.061	0.058	0.06
2. Roof			
Outside Surface (base case)	Medium	Light	Light
Outside Surface (DSM4)	Light	Light	Light
Absorbity	0.675	0.45	0.45
Overall U-value (Btu/hr.ft$^{2\,0}$ F)			
Base Case	0.223	0.108	0.041
DSM4	0.064	0.069	0.0298
C. LIGHTING DATA			
Power Density (PD)			
Basecase: Overhead Lighting	1.1 W/sq ft	0.8 W/sq ft	0.8 W/sq ft
DSM2	0.4 W/sq ft	0.2 W/sq ft	0.2 W/sq ft
D. END-USE EQUIPMENT			
Power Density (PD)			
Basecase	0.2 W/sq ft	0.5 W/sq ft	0.1 W/sq ft
DSM5	0.1 W/sq ft	0.38 W/sq ft	0.08 W/sq ft
E- PEOPLE			
Sensible Heat (W)	280	230	230
Latent Heat (W)	270	120	120
F- CENTRAL AC INPUT DATA			
Equipment Class	Packaged Rooftop Units	Split Air Handling Units	Packaged Rooftop Units
OA Requirement (CFM/ sq. ft)	7.4	2.8	7.2
Cooling T-stat (DSM1)	78 ^{0} F	78 ^{0} F	78 ^{0} F
Compressor & Fan Power			
Basecase	65 kW (8.5)	15.9 kW (9.6)	55 kW (9.1)
DSM3 (EER)	50 kW (11)	13.9 kW (11)	45 kW (11.1)

5.4 Simulation Findings

The results of simulation calculations are shown in details in the tables in the form of output reports and expressed as data for monthly and annual energy consumption and costs of consumed energy. Tables 5.3 (a), 5.3 (b) and 5.3 (c) below show a summary of the simulation results for the villa, apartment and traditional house respectively. The monthly consumption in the base case and with individual implementation of the five DSM options as well as their aggregated sum, savings in energy consumption and variation in maximum demand are also shown in the Tables.

From the simulation results, the following energy performance indicators could be identified:

a) The annual energy consumption for the existing dwellings in the base case, i.e. in the normal operating conditions, is shown in Table 5.2. In all models of buildings, simulation calculations gave higher rates of annual consumption relative to that resulted from energy audits and measurements. The reasons of this difference is, most likely, due to:

- The mismatch between buildings actual parameters and data imposed to simulate the building, such as types of wall and roof insulation and occupancy and other schedules.
- Rough estimates of monthly and annual consumption based on audits and measurements due to the lack of accuracy of billing and metering systems as well as short periods of measurements.
- The effect of climatic conditions on simulation results.

Table 5.2 - Estimates of Monthly and Annual Energy Consumption (Base Case)

Method	**Villa**		**Apartment**		**Traditional House**	
	Monthly	**Annual**	**Monthly**	**Annual**	**Monthly**	**Annual**
1. Audits (kWh)	8847	106164	2019	24228	7013	84156
2. Measurements (kWh)	8691	104288	2021	24255	6808	81694
3. Simulation (kWh)	11393	136721	2438	29260	7677	92128
Max. Deviation (%)	**24**		**17**		**11**	

b) The effect of imposing five DSM energy conservation measures was predicted in the simulation results as follows:

- The estimated annual energy consumption reduced, for the villa, from 136721 kWh (base case) to 115271 kWh by increasing the thermostat setting from 75 ^{0} F (23.9 ^{0} C) to 78 ^{0} F (25.6 ^{0} C)[2]. Similarly for the apartment and traditional house, the annual consumption reduced from 28908 kWh and 92129 kWh to 22977 kWh and 77588 kWh respectively.

- Calculations show that annual energy consumption reduced, for the villa, from 136721 kWh (base case) to 113967 kWh by replacing the incandescent lamps of rated power 40 W and 100 W to CFL of rated power 7 W and 25 W respectively. This energy efficiency measure is called DSM2. As a conservative approach, only 75% of the overhead lamps are replace giving a light power density (LPD) of 0.2 W/ft^2 instead of an existing value of 0.8 W/ft^2. Similarly simulation results for the apartment and traditional house indicated that annual consumption was reduced from 28908 kWh and 92129 kWh to 24131 kWh and 74619 kWh respectively.
- By upgrading the existing AC systems having EER ranges from 8.5 to 9.6 to more efficient systems with EER about 11, the reduction in energy consumption reached 22918 kWh, 2918 kWh and 12261 kWh for the villa, apartment and traditional house respectively.
- The simulation of the fourth DSM measure, which assumes the use of better wall and roof insulation resulted a reduction in annual energy consumption reached 3144 kWh for the villa, 156 kWh for the apartment and 2821 kWh for the traditional house.

[2] This is a conservative approach, since the actual setting of thermostat is usually less than 23 ^{o}C

- The last simulated DSM option assumes the use of more efficient end-use equipment. The predicted reductions in annual consumption are: 6305 kWh for villa, 442 kWh for apartment and 2473 kWh for the traditional house.
- Simultaneous implementation of the above five DSM measures indicated an aggregated sum of energy reduction reached 89311 kWh (65.3%) for the villa, 12912 kWh (44.7%) for the apartment and 43860 kWh (47.6%) for the traditional house.

The analysis of the above results, as well as, other DSM policy options will be discussed in Chapter 6.

Table 5.3 (a) - Villa Monthly Simulation Results

Month	Base Case			DSM1			DSM2			DSM3			DSM4			DSM5			DSM Total		
	Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)	
		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C
Jan	9,10	0	3194	9,10	0	3194	4,7	0	2047	9,1	0	3194	9,1	0	3194	8,6	0	2860	4	0	1447
Feb	9,10	0	2869	9,10	0	2869	4,7	0	1833	9,1	0	2869	9,1	0	2869	8,6	0	2572	4	0	1299
Mar	12,00	484	3150	10,60	264	3150	6,4	287	2005	11,3	372	3150	13,1	541	3150	11,3	426	2827	4,6	191	1425
Apr	20,90	3242	3086	18,40	2252	3086	13,9	2645	1976	18,2	2494	3086	18,7	2478	3086	20,1	3093	2764	7,7	786	1398
May	41,50	12001	3194	35,60	9228	3194	32,2	10709	2047	34	9231	3194	33,3	8112	3194	40,3	11660	2860	15	3505	1447
Jun	50,00	16510	3045	42,90	13014	3045	40,3	15080	1935	40,6	12700	3045	38,7	10760	3045	48,8	16138	2733	18,1	5037	1377
Jul	57,90	19564	3194	49,80	15583	3194	47,8	18037	2047	46,6	15049	3194	43,9	12602	3194	56,6	19161	2860	21,1	6072	1447
Aug	65,10	22461	3153	55,90	18018	3153	54,3	20747	2006	52,2	17277	3153	49,3	14554	3153	63,7	22020	2830	23,9	7124	1426
Sep	57,20	16274	3083	49,10	12860	3083	46,9	14838	1975	46,1	12519	3083	43,9	10847	3083	55,9	15904	2761	20,9	5114	1397
Oct	37,10	8766	3186	31,90	6634	3186	29,7	7692	2044	30,7	6743	3186	30	6265	3186	36	8488	2852	13,6	2636	1444
Nov	9,10	0	3045	9,10	0	3045	4,7	0	1935	9,1	0	3045	9,1	0	3045	8,6	0	2733	4	0	1377
Dec	9,10	0	3219	9,10	0	3219	4,7	0	2082	9,1	0	3219	9,1	0	3219	8,6	0	2874	4	0	1461
AVG.	**31,51**	**8275**	**3118**	**28**	**6488**	**3118**	**24**	**7503**	**1994**	**26**	**6365**	**3118**	**26**	**5513**	**3118**	**31**	**8074**	**2794**	**12**	**2539**	**1412**
Total		**99303**	**37418**		**77853**	**37418**		**90035**	**23932**		**76385**	**37418**		**66159**	**37418**		**96890**	**33526**		**30465**	**16945**
Total	**378,10**	**136721**		**330,60**	**115271**		**290,30**	**113967**		**316,10**	**113803**		**307,30**	**103577**		**367,10**	**130416**		**140,90**	**47410**	
Saving	**0**	**0**		**47,50**	**21450**		**87,80**	**22754**		**62,00**	**22918**		**70,80**	**33144**		**11,00**	**6305**		**237,20**	**89311**	
% Sav.	**0%**	**0%**		**12,6%**	**15,7%**		**23,2%**	**16,6%**		**16,4%**	**16,8%**		**18,7%**	**24,2%**		**2,91%**	**4,6%**		**62,7%**	**65,3%**	

DSM1 Thermostat Resetting from 75 to 78 ^{o} F

DSM2 Replacing 80% of Incandescent Bulbs to CFL

DSM3 Upgrade A/C Equipment to Efficient Units with EER = 11

DSM4 Increase Wall and Roof Insulation (R from 4 to 16 hr.ft^{2}.^{O}F) / Btu

DSM5 Use Energy Efficient End-Use Equipment

DSM Aggregate Implementation of All DSM Options (∑DSM1 to DSM5)

Table 5.3 (b) - Apartment Monthly Simulation Results

Month	Base Case			DSM1			DSM2			DSM3			DSM4			DSM5			DSM Total		
	Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)	
		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C
Jan	1,9	0	485	1,9	0	485	0,9	0	241	1,9	0	485	1,9	0	485	1,8	0	462	0,8	0	218
Feb	1,9	0	438	1,9	0	438	0,9	0	218	1,9	0	438	1,9	0	438	1,8	0	417	0,8	0	197
Mar	2,1	70	485	2	49	485	1	50	241	2,1	61	485	2,2	71	485	2,1	69	462	0,9	43	218
Apr	4,3	666	469	3,6	384	469	2,8	542	233	4	582	469	4,3	665	469	4,1	655	447	1,9	237	211
May	9,1	2737	485	7,6	1964	485	7,2	2469	241	8,3	2393	485	9,1	2723	485	9	2713	462	4,9	1484	218
Jun	11,4	3890	469	9,5	2917	469	9,3	3591	233	10,2	3401	469	11,3	3866	469	11,2	3863	447	6,5	2286	211
Jul	13,2	4651	485	11	3547	485	11,1	4333	241	11,8	4066	485	13,1	4618	485	13	4622	462	7,8	2817	218
Aug	15,2	5531	485	12,8	4281	485	13	5177	241	13,6	4836	485	15,2	5492	485	15	5499	462	9,2	3421	218
Sep	12,8	3775	469	10,6	2832	469	10,9	3477	233	11,4	3300	469	12,7	3745	469	12,6	3748	447	7,5	2207	211
Oct	8,1	1879	485	6,7	1294	485	6,5	1655	241	7,3	1642	485	8	1863	485	8	1858	462	4,3	934	218
Nov	1,9	0	469	1,9	0	469	0,9	0	233	1,9	0	469	1,9	0	469	1,8	0	447	0,8	0	211
Dec	1,9	0	485	1,9	0	485	0,9	0	241	1,9	0	485	1,9	0	485	1,8	0	462	0,8	0	218
AVG.	**7,0**	**1933,3**	**475,8**	**6,0**	**1439,0**	**475,8**	**5,5**	**1774,5**	**236,4**	**6,4**	**1690,1**	**475,8**	**7,0**	**1920,3**	**475,8**	**6,9**	**1918,9**	**453,3**	**3,9**	**1119,1**	**213,9**
Sub-Tot.		**23199,0**	**5709,0**		**17268,0**	**5709,0**		**21294,0**	**2837,0**		**20281,0**	**5709,0**		**23043,0**	**5709,0**		**23027,0**	**5439,0**		**13429,0**	**2567,0**
Total		**28908,0**			**22977,0**			**24131,0**			**25990,0**			**28752,0**			**28466,0**			**15996,0**	
Saving	**0,0**	**0,0**		**1,0**	**5931,0**		**1,5**	**4777,0**		**0,6**	**2918,0**		**0,0**	**156,0**		**0,1**	**442,0**		**0,0**	**12912,0**	
% Sav.	**0,0%**	**0,0%**		**14,8%**	**20,5%**		**22,0%**	**16,5%**		**8,9%**	**10,1%**		**0,0%**	**0,5%**		**1,4%**	**1,5%**		**43.9%**	**44,7%**	

DSM1 Thermostat Resetting from 75 to 78 ^{o} F

DSM2 Replacing 80% of Incandascent Bulbs to CFL

DSM3 Upgrade A/C Equipment to Efficient Units with EER = 11

DSM4 Increase Wall and Roof Insulation (R from 4 to 16 hr.ft^2.^{O}F) / Btu

DSM5 Use Energy Efficient End-Use Equipment

DSM Aggregate Implementation of All DSM Options (∑DSM1 to DSM5)

Table 5.3 (c) Traditional House Monthly Simulation Results

Month	Base Case			DSM1			DSM2			DSM3			DSM4			DSM5			DSM Total		
	Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)		Max. Demand (kW)	Energy Cons. (kWh)	
		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C		A/C	Non A/C
Jan	6	0	1800	6	0	1800	2,4	0	968	6	0	1800	6	0	1800	5,8	0	1677	2,2	0	844
Feb	6	0	1619	6	0	1619	2,4	0	867	6	0	1619	6	0	1618	5,8	0	1508	2,2	0	757
Mar	8	412	1783	6,7	263	1783	3,2	263	949	7,9	340	1783	8,1	371	1783	7,7	306	1664	2,9	218	830
Apr	15,1	2527	1740	13,5	1824	1740	9,8	2027	934	13,7	2090	1740	15,1	2403	1740	14,8	2369	1621	6,5	970	815
May	30,5	8794	1800	26,3	6911	1800	23,7	7733	968	26,3	7275	1800	30,2	8404	1800	30,1	8597	1677	15,8	4557	844
Jun	37,2	11949	1721	32	9560	1721	29,7	10760	915	31,8	9885	1721	36,8	11425	1721	36,7	11806	1606	19,9	6554	800
Jul	42,5	13949	1800	36,4	11243	1800	34,9	12676	968	36	11540	1800	41,9	13390	1800	42	13879	1677	23,5	7842	844
Aug	48,1	15867	1781	41,2	12840	1781	40	14429	949	40,6	13127	1781	47,4	15271	1781	47,5	15816	1662	27	8993	829
Sep	41,3	11399	1742	35,3	9109	1742	34,1	10203	935	35	9430	1742	40,7	11003	1742	40,8	11280	1623	23,1	6252	816
Oct	27,6	6085	1807	23,6	4691	1807	21,2	5199	970	23,7	5034	1807	27,2	5895	1807	27,1	5892	1684	14,4	2993	847
Nov	6	0	1721	6	0	1721	2,4	0	915	6	0	1721	6	0	1721	5,8	0	1606	2,2	0	800
Dec	6	0	1833	6	0	1833	2,4	0	991	6	0	1833	6	0	1833	5,8	0	1706	2,2	0	864
AVG.	**22,9**	**5915,2**	**1762,3**	**19,9**	**4703,4**	**1762,3**	**17,2**	**5274,2**	**944,1**	**19,9**	**4893,4**	**1762,3**	**22,6**	**5680,2**	**1762,2**	**22,5**	**5828,8**	**1642,6**	**11,8**	**3198,3**	**824,2**
Total		**70982**	**21147**		**56441**	**21147**		**63290**	**11329**		**58721**	**21147**		**68162**	**21146**		**69945**	**19711**		**38379**	**9890**
Total		**92129**			**77588**			**74619**			**79868**			**89308**			**89656**			**48269**	
Saving	**0**	**0**		**2,9**	**14541**		**5,7**	**17510**		**2,9**	**12261**		**0,2**	**2821**		**0,4**	**2473**		**11,0**	**43860**	
% Sav.	**0%**	**0,0%**		**12,9%**	**15,8%**		**24,8%**	**19,0%**		**12,9%**	**13,3%**		**1,1%**	**3,1%**		**1,6%**	**2,7%**		**48,3%**	**47,6%**	

DSM1 Thermostat Resetting from 75 to 78 ^{o} F

DSM2 Replacing 80% of Incandescent Bulbs to CFL

DSM3 Upgrade A/C Equipment to Efficient Units with EER = 11

DSM4 Increase Wall and Roof Insulation (R from 4 to 16 hr.ft^{2}.^{O}F) / Btu

DSM5 Use Energy Efficient End-Use Equipment

DSM Aggregate Implementation of All DSM Options (∑DSM1 to DSM5)

5.5 Summary

Three types of audited dwellings - villa, apartment and traditional house - were selected for computer simulation. The tool used for simulation is the Carrier's Hourly Analysis Programme. Data imposed for simulation are gathered from actual results of detailed energy audits. Very limited building parameters were assumed based on market trends, such as the type of wall and roof insulation. Energy simulation is aimed primarily to evaluate the performance of the building and calculate the amount of saved energy under different DSM measures. Matching with audit and measurements is also an important issue to be investigated by simulation process.

The first simulation was carried out for the three dwellings in the base case condition; in which the performance of the building is examined under its actual existing condition and energy use. The simulation process was then repeated for the following five DSM energy conservation measures:

1. Thermostat resetting from 75 ^{0}F (23.9 ^{0}C) to 78 ^{0}F (25.6 ^{0}C).
2. Replacement of about 80% of the incandescent lamps of rated power 40 W and 100 W to CFL of rated power 7 W and 25 W respectively..
3. Upgrading existing AC systems to more efficient types with EER = 11, instead of 8.5 – 9.5 currently used.
4. The use of high insulation material for walls and roofs.
5. Upgrading the existing end-use equipment (refrigerators, washing machines, water heaters, etc.) with more efficient ones.

Other simulation scenarios were carried out including simultaneous implementation of "DSM1 + DSM2" and "DSM1 + DSM2 + DSM3", as well as the simultaneous implementation of all five DSM options five options as illustrated in Appendix 10.

Simultaneous implementation of the first three DSM options achieved an energy saving of 49.7%, 43.8% and 43.1% of the base case consumption for the villa, apartment and traditional house respectively; while the implementation of all five DSM options achieved savings in the base case annual consumption equal to 65.3%, 44.7% and 47.6% respectively.

Chapter 6

Analysis of Potential DSM Options

6.1 Introduction

The results of energy audits discussed in Chapter 4, and energy simulation carried out on three dwelling types: a villa, apartment and traditional house, through HAP programme and presented in Chapter 5, have shown attractive potentials for energy efficiency improvement and savings opportunities through the application of several of DSM energy efficiency measures. These results and the results of detailed energy audits as well as the potential applications of other DSM measures need further analysis.

The objective of this analysis is to identify the recommended portfolio of DSM energy conservation measures. The analysis will cover not only the identified technological DSM measures, but also the selection of the most appropriate policy measures suitable for the condition of Kuwait.

6.2 Analysis of Audit and Simulation Results

The energy performance of the selected dwellings based on detailed audits, measurements and simulation is discussed in this section.

6.2.1 *Base Case Condition*

The base case represents the actual existing energy performance of the audited and simulated types of dwellings. With reference to Table 5.2, Chapter 5, the annual energy consumption based on audit and simulation results was estimated for each dwelling type as: from 104 to 136 MWh for villa, from 24 to 29 MWh for apartment and from 82 to 92 MWh for traditional house. These rates of consumption indicate the following:

- The overall per capita consumption ranges from 10500 to 12850 kWh (the average for Kuwait is approximately 12900 kWh). This rate of consumption is extremely high and represents about 5 times the world average of electricity consumption (IEA statistics).

- Audit results indicate a wide range of specific energy consumption (SEC), or energy density; where for the apartment it reaches 8 kWh / ft^2 (85 kWh / m^2) and for the villa, SEC reaches 75 kWh / ft^2 (800 kWh / m^2).

The above indicators show high consumption rates as well as substantial potential of energy conservation and efficiency improvement.

The local national energy Code in buildings sets a maximum limit for lighting power density (LPD) to 15 W/m^2 (1.4 W/ft^2) and for the air conditioning system, the power density is limited to 65 W/m^2 (about 6.0 W/ft^2). Audit results have shown the LPD is satisfied for all selected dwellings. However, the LPD specified by the Code has to be reconsidered or updated in the case of using high efficiency lighting with the same level of luminance as conventional lighting.

For air conditioning systems, audit results have shown that only the apartment satisfies the PD of the Code, while in the case of villa and traditional house the PD reached approximately 3 times the specified limit. This indicates that air conditioning systems in the villa and traditional house are over-sized.

It was also observed during energy audits that efficient double glazed windows are used with minor potential for energy efficiency improvement, except the potential application glass coating, reduction of infiltration and effective use of shading.

6.2.2 *DSM Energy Conservation Opportunities*

The DSM energy conservation opportunities (ECOs) identified in the simulation process and presented in Chapter 5, will be highlighted in-depth in this section.

Table 6.1 and 6.2 show the impacts of DSM measures on energy consumption and peak demand in July respectively. The aggregate sum of energy savings and peak reductions are illustrated in Figures 6.1 and 6.2 respectively. The analysis of these results indicates:

- Immediate implementation of "no cost" DSM measure, in which the thermostat was reset from 75 ^{0} F (23.9 ^{0} C) to 78 ^{0} F (25.6 ^{0} C) achieved 15.7% energy saving and 14.1% reduction in peak demand in the case of villa, 20.5% saved energy and 15.8% peak reduction in the case of apartment, and similarly for the traditional house 15.8% and 14.3% respectively. This option is very attractive since it is simple and has an immediate payback period.

- It was clear from energy audits that most of lighting lamps used in all dwellings are normal incandescent bulbs of rated power 100 W and 40 W. By replacing these lamps to CFL of rated power 25 W and 7 W respectively, the potential energy savings ranges from 16.5% to 19% and peak reduction from 14.5% to 16.8% as shown in Tables 7.1 and 7.2. Simulation results indicate a reduction of approximately 9% in A/C consumption due to the implementation of this option.
- Simultaneous implementation of the above two DSM options has a potential energy savings reached 38.5% for the villa, 37.1% for the apartment and 33.7% for the traditional house.
- In the third DSM measure, we assumed the possibility of upgrading air conditioning system to new more efficient with energy efficiency ratio about 11 instead of 8.5 – 9.0 in the base case. The achieved energy savings ranges from 10% to 16% and peak demand reduction ranges from 1.6% to 1.9%.
- The fourth DSM option assumes the use of better roof and wall insulation. As predicted from simulation results, the amount of energy savings depends on the U-value of the insulating material and the colour of walls and roofs. For example, in the case of villa, light coloured roof achieved more than 20% savings in energy.
- In the fifth DSM option, it was assumed that the end-use appliances, mainly the refrigerators, washing machines, TV sets, and water heaters are replaced with high efficiency ones (25% increase in efficiency). Savings in energy achieved ranges from 1.5% to 4.6% and in peak demand reduction from 0.2% to 2.2%.

It is important to emphasize that the last two DSM options are usually implemented for new buildings, however, the last option could be implemented in the existing buildings when buying new appliance.

- The scenario of combining all five DSM options was run by the simulation giving an attractive potential aggregate saving as follows:

❖ For the villa: 65.3% saved energy and 47.6% reduction in peak demand.

❖ For the apartment: 44.7% saved energy and 39.5% reduction in peak demand.

- For the traditional house: 47.6% saved energy and 43.9% reduction in peak demand.

Figure 6.3 shows the distribution of energy consumption by end-use, in the base case and with five DSM options.

Table 6.1 - DSM Impact on Annual Energy Consumption (July)

Options	Villa			Apartment			Traditional House		
	Consum. (kWh)	Saving (kWh)	%	Consum. (kWh)	Saving (kWh)	%	Consum. (kWh)	Saving (kWh)	%
Base Case	136721	0	0%	28908	0	0%	92129	0	0%
DSM1	115271	21450	15,7 %	22977	5931	20,5 %	77588	14541	15,8 %
DSM2	113967	22754	16,6 %	24131	4777	16,5 %	74619	17510	19,0 %
DSM1 + DSM2	84101	52620	38.5 %	18415	10845	37.1 %	61050	31078	33.7 %
DSM3	113803	22918	16,8 %	25990	2918	10,1 %	79868	12261	13,3 %
DSM1+DSM2+DSM3	68785	67936	49.7 %	16455	12805	43.8 %	52461	39667	43.1 %
DSM4	103577	33144	24,2 %	28752	156	0,5%	89308	2821	3,1%
DSM5	130416	6305	4,6%	28466	442	1,5%	89656	2473	2,7%
∑DSM1 – DSM5	**47410**	**89311**	**65,3 %**	**15996**	**12912**	**44,7 %**	**48269**	**43860**	**47,6 %**

Table 6.2 - Impact of DSM Options on Peak Demand (July)

Options	Villa			Apartment			Traditional House		
	Peak Demand (kW)	Peak Reduction (kW)	%	Peak Demand (kW)	Peak Reduction (kW)	%	Peak Demand (kW)	Peak Reduction (kW)	%
Base Case	65,1	0,0	0,0%	15,2	0,0	0,0%	48,1	0,0	0,0%
DSM1	55,9	9,2	14,1%	12,8	2,4	15,8 %	41,2	6,9	14,3 %
DSM2	54,3	10,8	16,6%	13,0	2,2	14,5 %	40,0	8,1	16,8 %
DSM3	52,2	12,9	19,8%	13,6	1,6	10,5 %	40,6	7,5	15,6 %
DSM4	49,3	15,8	24,3%	15,2	2,1	0,0%	47,4	7,0	1,5%
DSM5	63,7	1,4	2,2%	15,0	0,2	1,3%	47,5	0,6	1,2%
DSM Aggregate	**23,9**	**41,2**	63,3%	**9,2**	**6,0**	39,5 %	**27,0**	**21,1**	43,9 %

Figure 6.1 Aggregate Annual Saving of DSM Options

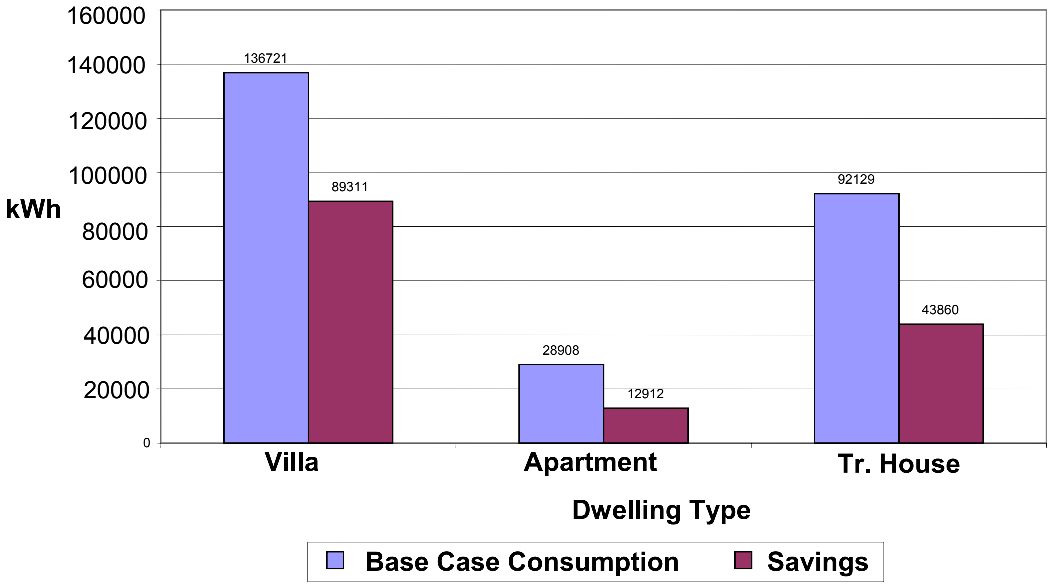


Figure 6.2 Aggregate Impact of DSM Options on Peak Demand

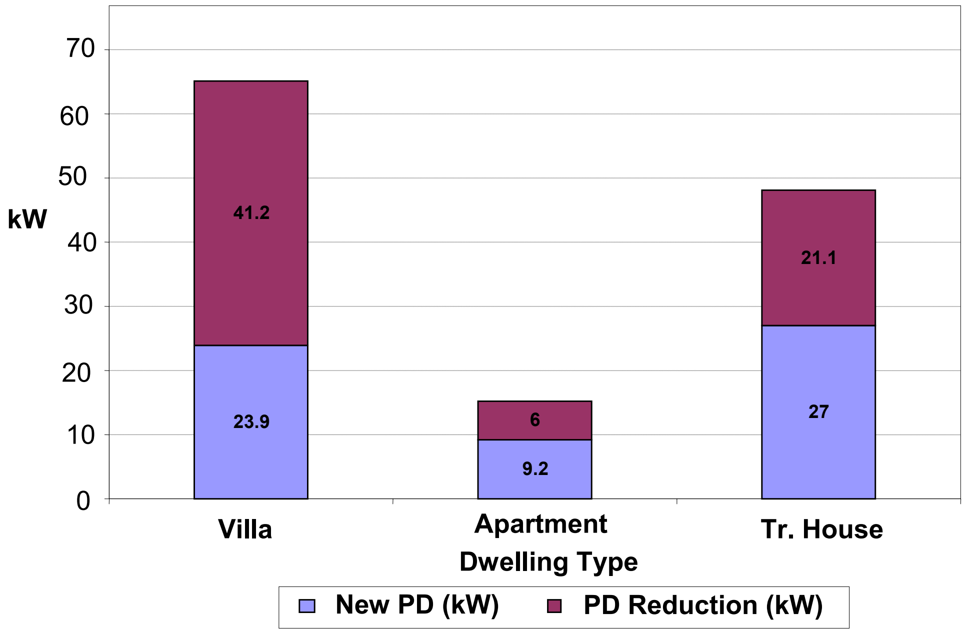
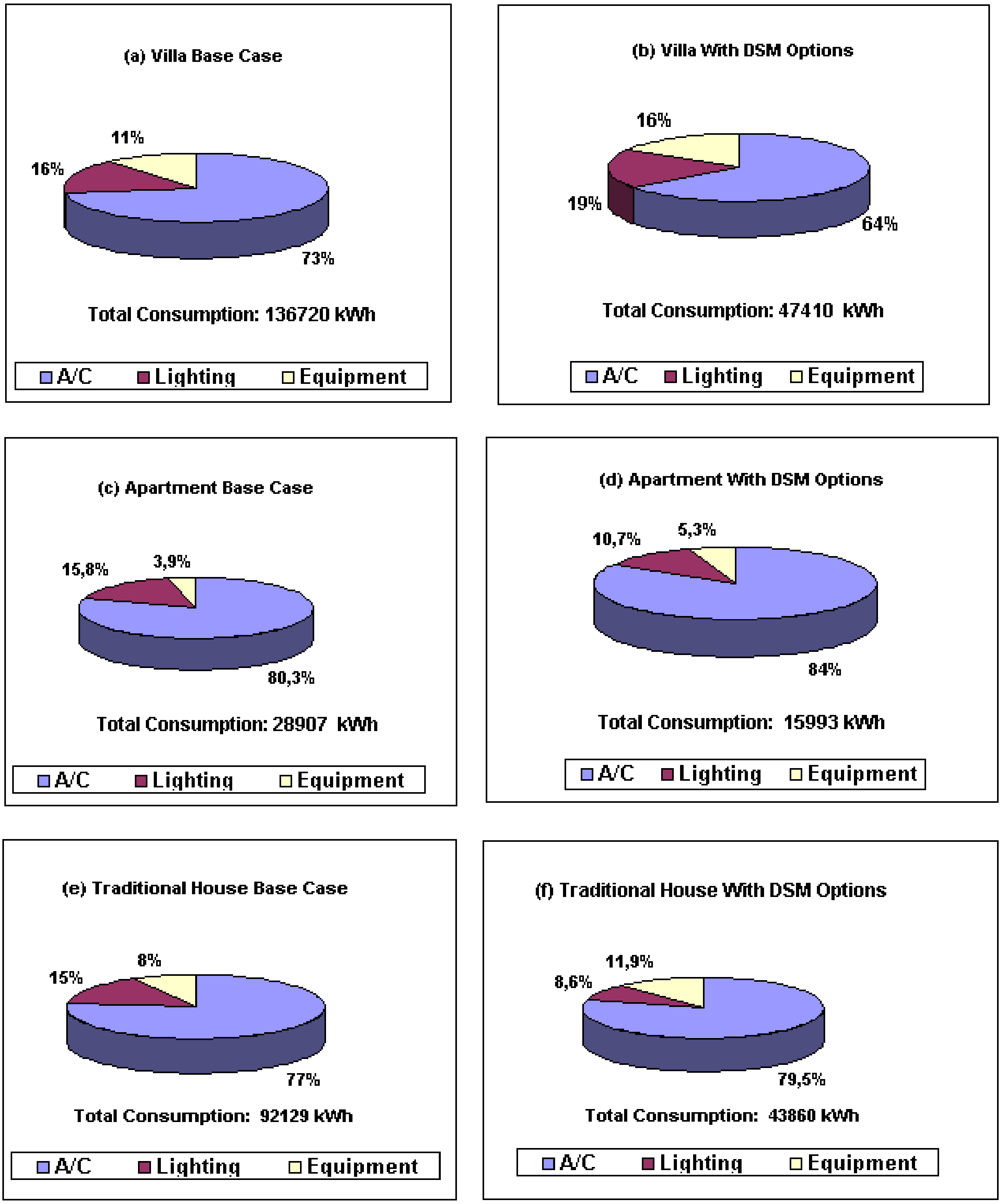


Figure 6.3 Distribution of Total Consumption by End-Use



6.3 Portfolio of DSM Technology Options

For further research analysis aiming to evaluate the overall DSM impact on the national level, it is necessary to prepare a list, or portfolio, of potential DSM opportunities that can, at the end on any DSM programme, can fulfil maximum energy savings and optimum peak demand reduction on the national level.

In this section, I shall propose a portfolio of DSM options based on energy audits, simulation process as well as the current condition in Kuwait related to electricity use and tariff.

The DSM portfolio will consist of two categories, technological and policy. The technological options are the five options evaluated by simulation process and illustrated in Figure 7.4. Policy DSM options will be proposed based on the condition in Kuwait and world experience.

6.4 Selection of DSM Policy Options

Based on the experience of many countries and energy situation in Kuwait, the following two important policy DSM measures may have a potential energy savings and peak demand reduction.

1. Increase of electricity tariff.
2. Energy Efficiency labels and standards for residential end-use appliances.

A brief description of these two DSM options is given below.

6.4.1 *Increase of Electricity Tariff*

MEW charges a flat tariff rate of 2 Fils (≈ 0.006 US$) per kWh to almost all its residential consumers. Only owners of beach cabins (chalets) have to pay 10 Fils (≈ 0.03 US$) per kWh. The low tariff rates have been in effect for more than 40 years. On the other hand, MEW states that the electricity production costs have been about 14 Fils (≈ 0.042 US$) per kWh delivered to the customer. Thus, the unit costs are 7 times higher than the average sales price. This means that the amount of subsidy is 12 Fils (≈ 0.036 US$) per kWh accounting about 86% of the electricity costs.

This condition might give the consumer of electricity the impression that electric power is available free of charge and electric energy is a cheap product, not necessary to be consumed in an efficient manner. Such a low tariff rate is one of the most important barriers to energy saving behaviour and to the introduction of energy efficiency DSM technologies.

In September 1999, a new tariff proposal was submitted by MEW. The proposal includes multi-part block rates for residential consumers and different tariffs for commercial and industrial consumers and beach cabins. The proposal suggests that the tariff rate for private consumers should be increased by 125% on average. Structure and rates of proposed residential tariff are described in Table 6.3. For both private houses and apartment buildings, the rates are divided into four blocks based on the average of monthly consumption. Price increase may reach 400% of the current price in case of consumption higher than 12000 kWh per month as shown in Table 6.3. For apartments, separate meters system is proposed in this tariff, one for non A/C loads and one for A/C as described in the table 6.3. Private houses with consumption less than 6000 kWh/month and apartments with less than 1500 kWh/month, the tariff will remain unchanged; only consumers with high consumption will be affected. These consumers usually can afford higher tariff and have a high savings potential.

Table 6.3 Proposed Electricity Tariffs for Residential Consumers

	Private House	**Apartment Building**			**Current Prices (Fils/kWh)**	**Proposed Price (Fils/kWh)**	**Proposed Increase (%)**
		Separate Meters	**Sep. Meters for non- A/C**	**Central A/C Meter**			
Consumption blocks in kWh	1 – 6000	1-1500	1-600	1-900	2	2	0%
	6001-9000	1501-3000	601-1200	901-1700	2	4	100%
	9001-12000	3001-6000	1201-2400	1701-3600	2	6	200%
	> 12000	> 6000	> 2400	> 3600	2	10	400%
Average					**2**	**4.5 ***	**125%**

* Average price based on the assumption that 70% of the consumers are in the lower two consumption brackets which pay an average price of 3 Fils/kWh, and that 30% pay an average of 8 Fils/kWh.

The tariff proposal has to be approved by the Council of Ministers and National Assembly in year 2000, however, it is still not yet approved facing a strong opposition from consumers who have been used to low electricity prices for more than a generation. The proposed tariff structure does not include two important tariff systems, which are already applied in many countries:

- The Time Of Use (TOU) tariff, and
- Capacity charge tariff.

6.4.2 *Energy Efficiency Labels and Standards*

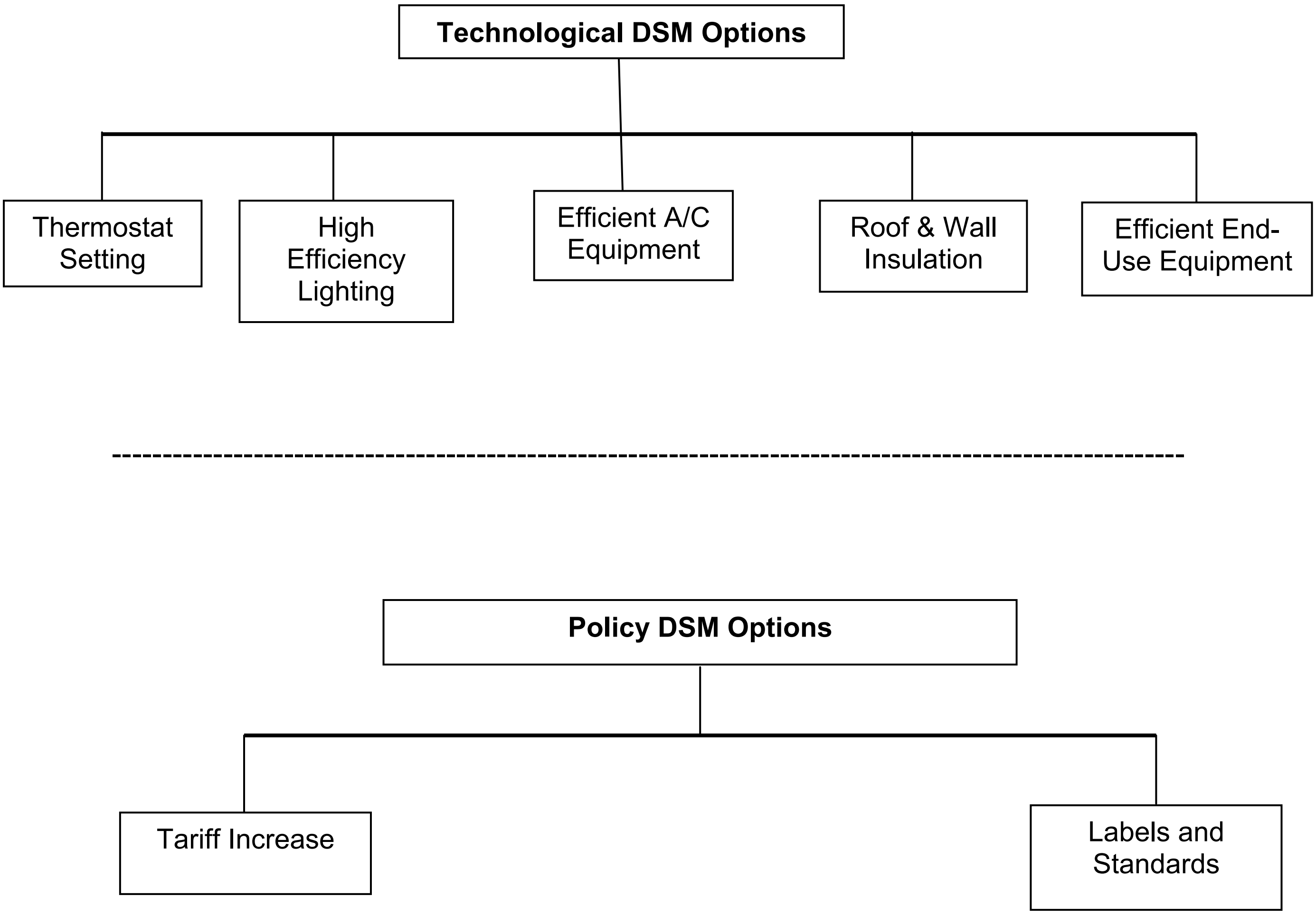
An energy efficiency standard is a regulation that prescribes minimum energy performance (that is, the maximum energy use) of an energy-using product (most commonly, household appliances, lighting products and other energy-consuming equipment). Energy efficiency labels are information labels attached to manufactured products indicating the product's Energy efficiency rating or estimated annual energy use in order to provide consumers with the data necessary to make an informed purchase. Appliance energy efficiency labelling and standards can be a primary force in the creation of stronger markets for energy-efficient goods and services. By gradually eliminating low-cost, inefficient appliance models and by stimulating the development of more efficient technologies, labels and standards increase a country's overall energy efficiency.

Based on the experience of many developing countries such as China, India and Algeria in this field, successful implementation of appliance labelling and efficiency standards in Kuwait can yield significant results.

Consumers need access to information about how their homes or businesses use energy, what energy – saving opportunities are open to them, and which products are energy- efficient and cost-effective choices. Energy - efficiency labels can play an important role in this consumer education.

For improving the efficiency of appliances, the most effective measures have generally been mandatory energy – efficiency standards applied to manufacturers. Many countries notably Canada, UK, China, the United States, Australia, Indonesia and Thailand, have established mandatory standards for a variety of appliances, most commonly refrigerators and air conditioners. Other countries have voluntary standards. Developing countries and less developed countries have often drawn on the established standards of other countries in developing their national standards.

Figure 6.4 – Portfolio of Proposed DSM Options



6.5 Summary

Based on detailed energy audits, results of HAP simulation, and the consumption trends as well as electricity tariff structure in Kuwait, seven DSM options are proposed in the DSM portfolio, five of them are technological measures and two are policy measures.

These technological measures are characterized briefly as follows:

- Increasing thermostat setting point from 75 ^{0} F (23.9 ^{0} C) to 78 ^{0} F (25.6 ^{0} C), could achieve a potential energy saving of, at least, 15% and peak demand reduction of 14% relative to the base case consumption.

- Replacement of conventional incandescent lamps with energy efficient CFLs of self ballasted and "screw" type design may achieve a potential savings of 16.5% in energy consumption and 15% in peak demand. This option gives a reduction in A/C consumption estimated at 9%.
- Upgrading the existing A/C equipment to more efficient ones with EER > 11 instead of 8.5 or 9. The results indicate potential savings in energy consumption 16.8%, 10.1% and 13.3% for the villa, apartment and traditional house respectively. The corresponding reduction in peak demand is 19.8%, 10.5% and 15.6% respectively.
- In case of simultaneous implementation of the first and second DSM options, the amount of aggregated sum of energy saved reached 38.5%, 37.1% and 33.7% for the villa, apartment and traditional house respectively. Assuming simultaneous implementation of the three DSM options, the total amount of saving as reported by simulation reached: 49.7% for villa, 43.8% for apartment and 43.1% for traditional house.
- The use of good wall insulation (DSM4) and the use of efficient end-use equipment (DSM5) may achieve energy savings and reduction in peak demand as shown in Tables 6.1 and 6.2. These two options are suitable for new construction. As shown in Table 6.1 and 6.2, relatively, large amount of saving is achieved in the villa by changing the walls and roof colour from "medium" to "light" and using wall insulation with U-value = 0.346 W / m^2K instead of 1.363 W / m^2K.

  Where as the two policy options are tariff increase and energy efficiency labels and standards.

Chapter 7

Evaluation and Ranking of DSM Options

7.1 Introduction

In Chapters 5 and 6, a combination of technological and policy DSM measures have been identified as potential opportunities to achieve the main goal of reducing energy consumption and peak demand. These DSM measures include the following:

- Thermostat setting (DSM1).
- High efficiency lighting (DSM2).
- Efficient air conditioning equipment (DSM3).
- Roof and wall insulation (DSM4).
- Efficient end-use equipment (DSM5).
- Tariff increase (DSM6).
- Labels and standards (DSM7).

The future penetration of these measures and their actual energy/power reductions are dependent on many uncertain factors, such as end-use technology development, market conditions, investment cost, customer acceptance and preference, etc. These uncertainties are considered by specifying a number of possible scenarios based on experts experience and their opinion on future economic and technological developments.

For any new DSM programme design, it is important to define what are the most cost-effective and suitable DSM measures and which one has the first priority in programme implementation. In this Chapter, the Analytic Hierarchy Process (AHP) will be used to evaluate the seven identified DSM measures and put them in priority order. The Chapter includes an illustrative example and the steps of calculations. At the end of the Chapter a priority list of the seven DSM options will be provided.

7.2 Criteria for Evaluation and Ranking

The criteria of evaluation the identified DSM options, on the sector level are complex and non-homogeneous. The presence of several non-homogeneous criteria in a multi-criteria decision making process requires a tool which is able to compare each of the options intelligently. In our research, we use the Analytic Hierarchy Process (AHP) or the Eigen-Vector Method (EVM), to help in setting priorities and making the best decision with respect to both qualitative and quantitative aspects. AHP is a powerful and flexible decision making process, that could be applied for any proposed DSM programme, when decision about priorities is required. The AHP technique[32], is based on expert's opinion and mathematical analysis, is applied to estimate uncertain DSM impacts on future electricity demand. Uncertainty is addressed with the use of discrete probability estimates of the occurrence of the different scenarios. The probability assignments are completed by pair-wise comparison of these scenarios and the Eigen-value analysis. Then, the expected penetration level and unit impact are computed using those probability weighted value. In order to determine the potential capacity and energy cost savings due to DSM effects, the estimated impacts are used to investigate the effect on the load duration pattern and integrated into supply-side planning process by using the new load duration curve model.

7.2.1 *The Analytic Hierarchy Process (AHP)*

The formulation of the decision hierarchy is a critical step in the AHP process because it effectively frames the problem and analysis in question. It uses a top down approach and involves decomposing the problem into a hierarchy of interrelated decision elements: goal, evaluation criteria and solution alternatives. Figure 7.1 shows a three level hierarchy for selecting an appropriate DSM implementation strategy. At the top of the hierarchy is the final goal which is defined as "Energy Savings and Peak Demand Reductions" in the present context. The factors, or criteria, that affect the choice of the best strategy are divided into six generic groups: Saved energy, peak demand reduction, investment cost, payback period, penetration rate and technology acceptance. In order to judge the relative importance of each criterion, we have to define the rating intensity scales for each criterion as shown in Table 8.1. Each criterion has a maximum weight of 9 and minimum of 1, divided into five scores as follows 9, 7, 5, 3 and 1. For example, the "payback period" criterion, will take the score 9 if it is immediate or very short (as in the case of thermostat setting), and the scores 7, 5, 3 and 1 for short (from 1 to 2 years), medium (from 2 to 4 years), long (from 4 to 5 years) and very long (> 5 years) payback periods respectively. The proposed weights and scores shown in Table 7.1 are based on the world experience in DSM projects implementation and in-depth interviews with experts in the field. Three experts, one from KISR[33] and two independent consultants having a long experience in DSM[34,35]

The third level consists of the DSM alternatives identified to satisfy the overall decision goal. Arranging the goal, criteria and alternatives in this manner allows the decision maker(s) to visualize the complex relationships inherent in the situation and assess the importance of each issue at each level.

7.3 Features of Identified DSM Options

In order to reduce the risk of Uncertainty, and to facilitate the pair-wise comparisons used in the AHP process, we shall try to emphasize the main features of each DSM alternative and predict its characteristics in terms of the criteria given in Table 7.1. This overview is mainly based on the results of audits, simulation as well as successful DSM programmes implemented in developing countries. Based on these features and interview with experts, the score of each DSM alternative is estimated as shown in Table 7.2. The problem of uncertainty may be clear with respect to some criteria, such as "penetration rate" and "technology acceptance". This problem is minimized, as much as possible, by taking the minimum scores as a conservative approach. Table 7.2 shows also a brief description of the technological DSM options. Regarding regulatory options (tariff increase and labels and standards), we shall try to assess its potential impact on energy consumption and peak demand as discussed in different resources[36, 37] Since the two policy options are not evaluated by simulation process, so we shall try, through the following assessment to estimate the potential of these options quantitatively as could be applied in Kuwait.

Table 7.1 Hierarchy Evaluation Criteria of DSM Options

Criteria	Definition	Weight	
		Value	For
1. Saved Energy	Expressed as the amount of saved energy in kWh or as a percentage of total annual energy consumption of the dwelling. Criteria weight is linearly proportional to the amount of energy saved	1 3 5 7 9	< 10% (Very low) 10 – 20% (Low) 20 – 30% (Medium) 30 – 40% (High) > 40% (Very high)
2. Peak Demand Reduction	The of kW reduction in peak demand. It is maximum when coincides with the national peak and minimum if it is out of peak.	1 3 5 7 9	< 10% (Very low) 10 – 20% (Low) 20 – 30% (Medium) 30 – 40% (High) > 40% (Very high)
3. Investment Cost	Defined as the investment cost for DSM measure implementation. It ranges from "No cost" to Very high cost.	1 3 5 7 9	Very high cost High cost Medium cost Low cost No Cost/Very low cost
4. Payback Period	The simple payback period (PB)is defined as: $$\text{PB Period} = \frac{\text{Total capital cost}}{\text{Net annual savings}}$$ The shorter PB period, the most cost-effective DSM option.	1 3 5 7 9	> 5 years (Very long) 4 – 5 years (Long) 2 – 4 years (Medium) 1 – 2 years (Short) < 1 year (Very short)
5. Penetration Level	The penetration level represents the potential spreading of the DSM option in the assigned sector. The target of any DSM programme is to achieve 100% penetration by the end of the project.	1 3 5 7 9	1 - 5% per year 5 – 10% per year 10 – 20% per year 20 – 30% per year > 30% per year
6. Technology Acceptance	It is important in any DSM programme design and implementation is not to select sophisticated technology that could not be promoted and accepted by the people. The contribution of local manufacturing in the technology applied is also important.	1 3 5 7 9	Low. Acceptance Medium Acceptance High Acceptance Very High Acceptance Full Acceptance

Source: Weight are proposed based on consultations with experts in DSM and designed to applicable in the AHP process.[33,34,35]

7.3.1 *Impact of Tariff Increase*

Tariff increase normally leads to a reduction in energy consumption. The short-run prices elasticity of electricity consumption tends to be in the range of – 0.1 to - 0.2, i.e. a tariff increase by 1% results in a consumption decrease by 0.1%. The effect of tariff changes increases in the long-run, when consumers have more possibilities to adapt their behaviour, therefore, long-run prices elasticity are higher than short-run elasticity: in the range of – 0.2 to – 0.3[37].

In 1987, a study performed by KISR to assess the impact of alternative electricity tariff on: energy consumption, equity for consumers and profitability for producers, government subsidy and macro-economic effects. The study was only concerned with the energy savings effect and did not estimate the effect on peak load.

To estimate demand functions for residential consumption, KISR used a combination of time series and cross section data. Cross section data was used to estimate the income elasticity of demand, while the time series data served to estimate the price elasticity of demand. Short-term price elasticity was found to be in the order of - 0.09 and medium-term elasticity (two to five years) in the order of - 0.30.

7.3.2 *Energy Efficiency Standards and Labelling (EES&L)*

The policy of energy efficient standards and labelling (EES & L) for end-use equipment has now been applied in over 60 countries. Strong efficiency policies for residential equipment used to be the near exclusive domain of industrialized economies, especially the United States, European Union and Japan. However, this situation has changed significantly with the development of policies, especially EES&L programmes. In the 15 years between 1990 and 2005, the number of such programmes worldwide has increased from 12 to over 60 (S. Wiel and J.E. McMahon 2005), including many developing countries. The growth in the number of EES&L programmes indicates that developing country governments are increasingly concerned with controlling Energy

Consumption and also that they view the experience of programmes in industrialized countries as having been successful. Indeed, there have been notable successes.

For example, standards already written into law in USA are expected to reduce residential sector consumption and carbon dioxide emissions by 8-9% by 2020 (Meyers, McMahon, McNeil et al. 2003). Another study indicates that policies in all OECD countries will likely reduce residential electricity consumption 12.5% in year 2020 compared to if no policies had been implemented to date (IEA 2003). Studies of impacts of EES&L programmes already implemented in developing countries are rare, but there a few encouraging examples. Mexico, for example, implemented its first minimum Efficiency Performance Standards (MEPS) on four major products in 1995. By 2005, only ten years later, standards on these products alone were estimated to have reduced annual national electricity consumption by 9% (Sanchez, McNeil et al. 2007). Many developing countries, including Kuwait, still have no efficiency policy regimes in place, and therefore have a high technical potential. Many have EES&L for only a few products or otherwise behind the world's best practices. For these reasons, a large effort should be done to understand demand trends, performance characteristics of existing appliances and the improvement potential in Kuwait.

Mandatory energy performance standards are important because they contribute positively to a nation's economy and provide relative certainty about the outcome (both timing and magnitude).

Labels also contribute positively to a nation's economy and increase the awareness of the energy-consuming public. Labelling programmes are designed to provide consumers with information, which enables them to compare the energy efficiency of the different appliances on sale. They aim at modifying the selection criteria of consumers by drawing their attention to the energy consumption of household appliances. Labelling programmes, however, cannot sufficiently transform the market and are usually completed by minimum performance standards in the great majority of countries.

The household appliances, selected under this study, that need to be standardized under an EES&L programme are based on the appliance share in household energy consumption. As in most countries, the EES&L programme could be implemented gradually in Kuwait by selecting specific appliance(s), such as refrigerators, and/or washing machines and air conditioning systems.

Figure 7.1 – AHP Block Diagram

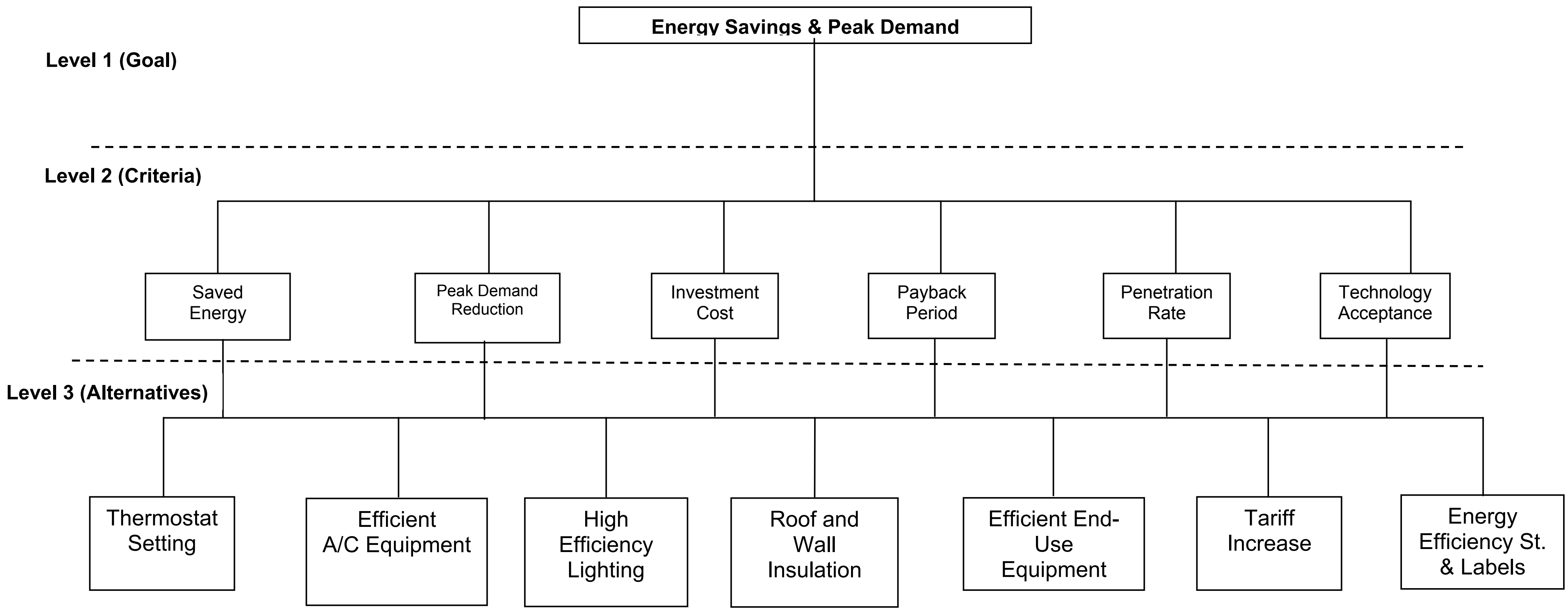


Table 7.2 Features and Proposed Scores of Identified DSM Options

DSM Option	Energy Saving	Peak Reduction	Invest. Cost(1)	Payback Period (2)	Penetration Rate (3)	Technology Acceptance (4)	Description
1. Thermostat Setting (DSM1)	Low (3)	Low (3)	No Cost (9)	Immediate (9)	Medium (5)	Very high (7)	The increase of thermostat set point from 75 ^{0} F (23.9^0 C) to 78 ^{0} F (25.6^0 C) is a simple and cost-effective DSM action. It has the advantage of obtaining an immediate payback period without requirement of any investment cost. Based on simulation results, the amount of saved energy ranges from 15% too 20% depending on the type of dwelling, and reduction in peak demand ranges from 14% to 16%. In most cases, the thermostat is set at lower temperature ≈ 70 ^{0} F (21^0 C), giving the opportunity of higher amount of savings (see note).
2. High efficiency lighting (DSM2)	Medium (5)	Low (3)	Medium (5)	Short (7)	High (5)	High (5)	Replacing of conventional incandescent lamps with compact fluorescent lamps (CFL) can achieve about 75% of energy used. The life span of the CFL is approximately 8 times that of the incandescent lamp. This option has the advantage of reducing the A/C load and relatively short payback period (1-2 years) and medium investment cost. Simulation results gave an energy savings ranging from 16% to 19% and peak demand reduction from 14.5 to 16.8%.
3. Efficient air-conditioning units (DSM3)	Low (3)	Low (3)	Medium (5)	Medium (5)	Very Low (1)	Medium (3)	The current stock of AC units are inefficient, most units have a power rating of 1.3 to 1.7 kW/ton. This corresponds to a Coefficient Of Performance (COP) of approximately 2.1 to 2.7, including both condenser and evaporator fans. From simulation results the saved energy ranges from 10% to 16.8.%, and the peak demand reduction ranges from 10.5% to 19.8%.
4. Increase roof and wall insulation (DSM4)	Medium (5)	Medium (5)	Medium (5)	Medium (5)	Very low (1)	Medium (5)	Good insulation for the building roofs and walls as well as light colour may achieve a potential reductions in energy and demand of A/C load. The life span of this measure is estimated at 30 years. Simulation indicated that the maximum energy saving achieved reached 24% by using better insulation and light colour in the roof. Almost the same percentage was also achieved in peak demand.
5. Efficient End-Use Equipment (DSM5)	Very low (1)	Very low (1)	Medium (5)	Long (3)	Very low (1)	Medium (3)	The end-use equipment included in this option are: refrigerators, washing machines, and water heaters. Refrigerator standards have nearly doubled over the last 10 years. It will be assumed that each household has, at least, one refrigerator and the average electricity consumption is 1500 kWh per unit per year. Replacing these inefficient units can reduce the annual consumption to 850 kWh, i.e. around 43%. As a percentage of the total annual dwelling's consumption, the maximum achieved energy saving, by simulation, was only 4.6% and peak demand reduction was 2.2%. Note that water heaters are used only in winter months.
6. Tariff Increase (DSM6)	Low (3)	Very Low (1)	Very Low (9)	Short (7)	Low (3)	Low (1)	See text.
7. Labels and Standards (DSM7)	Low (3)	Very low (1)	Medium (5)	Long (3)	Low (3)	Low (1)	See text.

Note: a) Based on the energy audits, some A/C thermostat were set at 75 F, thus we used as base case as a conservative approach

(1) Investment (incremental) cost: Low: < \$1000, Medium: \$1000 - \$10000, High: \$10,000 - \$100000, Very High: > \$ 100000.

(2) Payback Period: < 1year (very short), 1-3 years (short), 3-5 (medium), >5 years (long)

(3) & (4) are based on interviews with experts in DSM (see References 2, 3 and 4)

7.4 Example of AHP Calculations

The AHP procedure will be demonstrated in this example for illustration purposes. The basic steps developed by Saaty[38,39]are followed in this example for the selection of the best DSM option. Referring to Table 7.2 and the hierarchy of the problem shown in Figure 7.2, the following can be done manually or automatically by the AHP software, "Expert Choice"[40].

7.4.1 *Expert Choice:*[41,42]

With Expert Choice, we define our goals, identify the criteria and alternatives, and evaluate key trade-offs in a straight forward process. Expert Choice assists in building a model for our decision and leads us in judging, via pair-wise comparisons, the relative importance of the variables (DSM options). Expert Choice then synthesizes our judgments to arrive at a conclusion and allows us to examine how changing the weighting of our criteria affects our outcome.

As we create our decision model, we have to make certain assumptions (usually based on previous experience) about the relative importance or value of various criteria and alternatives (see Table 7.2). But what if we are not sure those assumptions are correct … or we recognize that they are subject to factors that may change over time? Expert Choice's five sensitivity Graphs will enable us to take some of the uncertainty out of our decision making by quickly and easily testing the results using "what if" scenarios. When we change the variables, Expert Choice promptly shows us the effect on the outcome.

A full range of reports – either printed in hard copy or pasted into other Windows applications – can be customized to individual needs for presenting results or documenting the decision making process. Reports may include the entire decision hierarchy in sideways or tree view, specific segments of the hierarchy, details of the synthesis process, or sensitivity analysis.

The steps used in our AHP example are as follows:

1. Constructing a set of pair-wise comparison matrices (size 7 x 7) to indicate the preferences or priority for DSM alternative in terms of how it contributes to each criterion as shown in Table 7.3(a).

2. Synthesizing the pair-wise comparison matrix as shown in Table 7.3 (c). Synthesizing is carried out by dividing each element of the matrix by its column total. For example the value 0.130 in Table 7.3 (c) is obtained by dividing 1.0 (from Table 7.3 (b) by 7.667, the sum of the column items in Table 7.3 (b) (1 + 1.667 + 1 + 1.667 + 0.333 + 1 + 1). The priority vector shown in Table 7.3 (c) can be obtained by finding the raw averages. For example, the priority of DSM1 with respect to the criterion "Saved Energy" in Table 7.3 (c) is calculated by dividing the sum of the rows (0.13 + 0.13 + 0.083 + 0.13 + 0.13 + 0.13 + 0.13) by the number of DSM options (columns), i.e., 7, in order to obtain the value 0.124. The priority vector for "Saved Energy", indicated in Table 7.3 (c) is given below for all DSM.

0.124
0.219
0.131
0.219
0.044
0.131
0.131

3. Calculating the consistency ratio, by using the eigenvalue as follows:

$$\mathbf{0,124}\begin{matrix}1,000\\1,667\\1,000\\1,667\\0,333\\1,000\\1,000\end{matrix} + \mathbf{0,219}\begin{matrix}0,600\\1,000\\0,600\\1,000\\0,200\\0,600\\0,600\end{matrix} + \mathbf{0,131}\begin{matrix}0,600\\1,667\\1,000\\1,667\\0,333\\1,000\\1,000\end{matrix} + \mathbf{0,219}\begin{matrix}0,600\\1,000\\0,600\\1,000\\0,200\\0,600\\0,600\end{matrix} +$$

$$\mathbf{0,044}\begin{matrix}3,000\\5,000\\3,000\\5,000\\1,000\\3,000\\3,000\end{matrix} + \mathbf{0,131}\begin{matrix}1,000\\1,667\\1,000\\1,667\\0,333\\1,000\\1,000\end{matrix} + \mathbf{0,131}\begin{matrix}1,000\\1,667\\1,000\\1,667\\0,333\\1,000\\1,000\end{matrix} = \begin{matrix}\mathbf{0.860}\\\mathbf{1.521}\\\mathbf{0.912}\\\mathbf{1.521}\\\mathbf{0.304}\\\mathbf{0.912}\\\mathbf{0.912}\end{matrix}$$

(Weighted sum matrix)

Dividing all the elements of the weighted sum matrices by their respective priority vector elements, we obtain:

0.86/0.124 = 6.940, 1.521/0.219 = 6.950, 0.912/0.131 = 6.960, 1.521/0.219 = 6.950
0.304/0.044 = 6.910, 0.912/0.131 = 6.960, 0.912/0.131 = 6.96

We then compute the average of these values to get the eigenvalue λ_{max}

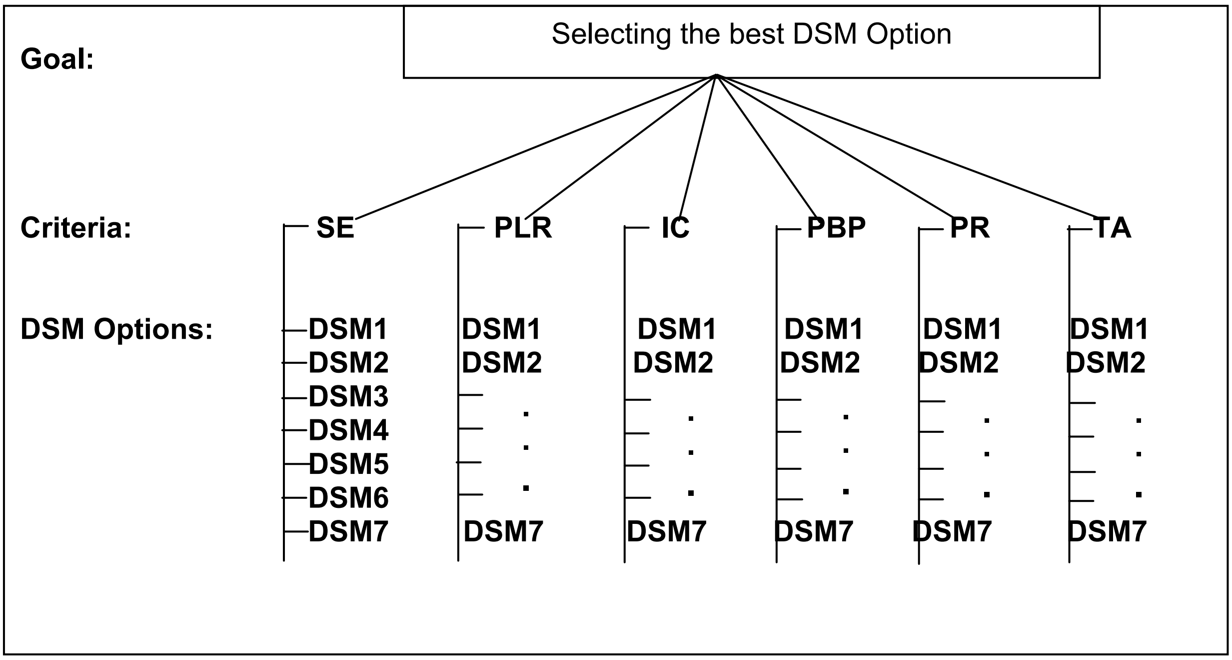
$$\lambda_{max} = \frac{(6.94 + 6.95 + 6.96 + 6.95 + 6.91 + 6.96 + 6.96)}{7} = 6.95$$

We now find the consistency index, CI, as follows:

Consistency Index		CI	=	(λ max-n)/(n-1)	= -0,010	
	Where	N	=		7	
According to Saaty:		Assume the random consistency for the size of matrix = 7			RI = 1.32	
Consistency Ratio		CR	=	CI/RI	-0,0073	< 0.1

As the value of CR is less than 0.1, the judgements are acceptable. Similarly, the pair-wise comparisons matrices and priority vectors for the remaining criteria can be evaluated as shown in Tables 7.4-7.8 respectively.

Figure 7.2 – Hierarchy Structure of DSM Options



SE = Saved Energy　　PLR = Peak Load Reduction
IC = Investment Cost　　PBP = Payback Period
PR = Penetration Rate　　TA = Technology Acceptance

Table 7.3 (a) - Pair wise Comparison for "Saved Energy"

Saved Energy	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7
DSM1	1 (3/3)	(3/5)	(3/5)	(3/5)	(3/1)	(3/3)	(3/3)
DSM2	(5/3)	1 (5/5)	(5/3)	(5/5)	(5/1)	(5/3)	(5/3)
DSM3	(3/3)	(3/5)	1 (3/3)	(3/5)	(3/1)	(3/3)	(3/3)
DSM4	(5/3)	(5/5)	(5/3)	1 (5/5)	(5/1)	(5/3)	(5/3)
DSM5	(1/3)	(1/5)	(1/3)	(1/5)	1 (1/1)	(1/3)	(1/3)
DSM6	(3/3)	(3/5)	(3/3)	(3/5)	(3/1)	1 (3/3)	(3/3)
DSM7	(3/3)	(3/5)	(3/3)	(3/5)	(3/1)	(3/3)	1 (3/3)

Table 7.3 (b) - Pair wise Comparison for "Saved Energy"
(With Column Totals)

Saved Energy	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7
DSM1	1,000	0,600	0,600	0,600	3,000	1,000	1,000
DSM2	1,667	1,000	1,667	1,000	5,000	1,667	1,667
DSM3	1,000	0,600	1,000	0,600	3,000	1,000	1,000
DSM4	1,667	1,000	1,667	1,000	5,000	1,667	1,667
DSM5	0,333	0,200	0,333	0,200	1,000	0,333	0,333
DSM6	1,000	0,600	1,000	0,600	3,000	1,000	1,000
DSM7	1,000	0,600	1,000	0,600	3,000	1,000	1,000
SUM	**7,667**	**4,600**	**7,267**	**4,600**	**23,000**	**7,667**	**7,667**

Table 7.3 (c) - Synthesized Matrix for "Saved Energy"

Saved Energy	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	0,130	0,130	0,083	0,130	0,130	0,130	0,130	**0,124**
DSM2	0,217	0,217	0,229	0,217	0,217	0,217	0,217	**0,219**
DSM3	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
DSM4	0,217	0,217	0,229	0,217	0,217	0,217	0,217	**0,219**
DSM5	0,043	0,043	0,046	0,043	0,043	0,043	0,043	**0,044**
DSM6	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
DSM7	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
SUM	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**

Table 7.4 - Pair wise Comparison for "Peak Load Reduction"

Peak Load Reduction	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	1 (3/3)	(3/3)	(3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,179**
DSM2	(3/3)	1(3/3)	(3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,179**
DSM3	(3/3)	(3/3)	1 (3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,197**
DSM4	(5/3)	(5/3)	(5/3)	1 (5/5)	(5/1)	(5/1)	(5/1)	**0,267**
DSM5	(1/3)	(1/3)	(1/3)	(1/5)	1 (1/1)	(1/1)	(1/1)	**0,060**
DSM6	(1/3)	(1/3)	(1/3)	(1/5)	(1/1)	1(1/1)	(1/1)	**0,060**
DSM7	(1/3)	(1/3)	(1/3)	(1/5)	(1/1)	(1/1)	1(1/1)	**0,060**

Table 7.5 - Pair wise Comparison for "Investment Cost"

Investment Cost	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	1	(9/5)	(9/5)	(9/5)	(9/5)	(9/9)	(9/5)	**0,209**
DSM2	(5/9)	1	(5/5)	(5/5)	(5/5)	(5/9)	(5/5)	**0,116**
DSM3	(5/9)	(5/5)	1	(5/5)	(5/5)	(5/9)	(5/5)	**0,116**
DSM4	(5/9)	(5/5)	(5/5)	1	(5/5)	(5/9)	(5/5)	**0,116**
DSM5	(5/9)	1	(5/5)	(5/5)	1	(5/9)	(5/5)	**0,116**
DSM6	(9/9)	(9/5)	(9/5)	(9/5)	(9/5)	1	(9/5)	**0,209**
DSM7	(5/9)	(5/5)	(5/5)	(5/5)	(5/5)	(5/9)	1	**0,116**

Table 7.6 - Pair wise Comparison for "Payback Period"

Investment Cost	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	1	(9/7)	(9/5)	(9/5)	(9/3)	(9/7)	(9/3)	**0.231**
DSM2	(7/9)	1	(7/5)	(7/5)	(7/3)	(7/7)	(7/3)	**0.180**
DSM3	(5/9)	(5/7)	1	(5/5)	(5/3)	(5/7)	(5/3)	**0.128**
DSM4	(5/9)	(5/7)	(5/5)	1	(5/3)	(5/7)	(5/3)	**0.128**
DSM5	(3/9)	(3/7)	(3/5)	(3/5)	1	(3/7)	(3/3)	**0,077**
DSM6	(7/9)	(7/7)	(7/5)	(7/5)	(7/3)	1	(7/3)	**0,180**
DSM7	(3/9)	(3/7)	(3/5)	(3/5)	(3/3)	(3/7)	1	**0,077**

Table 7.7 - Pair wise Comparison for "Penetration Rate"

Penetration Rate	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	**1**	(5/5)	(5/1)	(5/1)	(5/1)	(5/3)	(5/1)	**0,294**
DSM2	(5/5)	**1**	(5/1)	(5/1)	(5/1)	(5/3)	(5/1)	**0,294**
DSM3	(1/5)	(1/5)	**1**	(1/1)	(1/1)	(1/3)	(1/1)	**0,059**
DSM4	(1/5)	(1/5)	(1/1)	**1**	(1/1)	(1/3)	(1/1)	**0,059**
DSM5	(1/5)	(1/5)	(1/1)	(1/1)	**1**	(1/3)	(1/1)	**0,059**
DSM6	(3/5)	(3/5)	(3/1)	(3/1)	(3/1)	**1**	(3/1)	**0,176**
DSM7	(1/5)	(1/5)	(1/1)	(1/1)	(1/1)	(1/3)	**1**	**0,059**

Table 7.8 - Pair wise Comparison for "Technology Acceptance"

Technical Acceptance	DSM1	DSM2	DSM3	DSM4	DSM5	DSM6	DSM7	Priority Vector
DSM1	1	(7/5)	(7/3)	(7/5)	(7/3)	(7/1)	(7/1)	**0,280**
DSM2	(5/7)	1	(5/3)	(5/5)	(5/3)	(5/1)	(5/1)	**0,200**
DSM3	(3/7)	(3/5)	1	(3/5)	(3/3)	(3/1)	(3/1)	**0,120**
DSM4	(5/7)	(5/5)	(5/3)	1	(5/3)	(5/1)	(5/1)	**0,200**
DSM5	(3/7)	(3/5)	(3/3)	(3/5)	1	(3/1)	(3/1)	**0,120**
DSM6	(1/7)	(1/5)	(1/3)	(1/5)	(1/3)	1	(1/1)	**0,040**
DSM7	(1/7)	(1/5)	(1/3)	(1/5)	(1/3)	(1/1)	1	**0,040**

Now the pair-wise comparison is also used to set priorities for all six criteria in terms of importance of each in contributing to the overall goal. Table 7.9 shows the pair-wise comparison matrix and priority vector for the six criteria. Of course, the highest priority, or extremely preferred, is given to the two criteria: saved Energy and peak load reduction; followed by two equally strongly preferred: the investment cost and the payback period; and with less importance come the last two criteria: Penetration rate and technology acceptance, as shown in Table 7.9.

Table 7.9 - Pair-wise Comparison Matrix for the Six Criteria (With Column Totals)

	SE	PLR	IC	PBP	PR	TA	Priority Vector
SE	1,000	1,000	1,286	1,286	1,800	3,000	**0,225**
PLR	1,000	1,000	1,286	1,286	1,800	3,000	**0,225**
IC	0,778	0,778	1,000	1,000	1,400	2,333	**0,175**
PBP	0,778	0,778	1,000	1,000	1,400	2,333	**0,175**
PR	0,556	0,556	0,714	0,714	1,000	1,667	**0,125**
TA	0,333	0,333	0,429	0,429	0,600	1,000	**0,075**
SUM	**4,444**	**4,444**	**5,714**	**5,714**	**8,000**	**13,333**	**1,000**

The last step is to combine the criterion priorities and the priorities of each DSM alternative relative to each criterion in order to develop an overall priority ranking of the

DSM options which is termed as the priority matrix as illustrated in Table 7.10. The last column of the Table represents the calculated overall priority vector.

Table 7.10 - Priority Matrix for DSM Options

	SE (0,225)	PLR (0,225)	IC (0,175)	PBP (0,175)	PR (0,125)	TA (0,075)	Overall Priority Vector
DSM1	0,124	0,179	0,209	0,231	0,294	0,280	**0,203**
DSM2	0,219	0,179	0,116	0,179	0,294	0,200	**0,193**
DSM3	0,131	0,197	0,116	0,128	0,059	0,120	**0,133**
DSM4	0,219	0,267	0,116	0,128	0,059	0,200	**0,175**
DSM5	0,044	0,060	0,116	0,077	0,059	0,120	**0,073**
DSM6	0,131	0,060	0,209	0,179	0,176	0,040	**0,136**
DSM7	0,131	0,060	0,116	0,077	0,059	0,040	**0,087**

It is clear from Table 7.10, that DSM1– Increasing of thermostat set point – is the best alternative for any future DSM strategy. Ranking all seven DSM options according to their overall priorities is as follows:

DSM1 (20.3%), DSM2 (19.3%), DSM4 (17.5%), DSM6 (13.6%), DSM3 (13.3%), DSM7 (8.7%) and DSM5 (7.3%). For more explanations and details of the example of AHP calculations refer to Appendix 7.

7.4.2 *Sensitivity Analysis*

A sensitivity analysis could be applied to investigate how sensitive the rankings of the alternatives are to changes in the importance of the criteria. Expert Choice offers five modes of graphical sensitivity analysis:

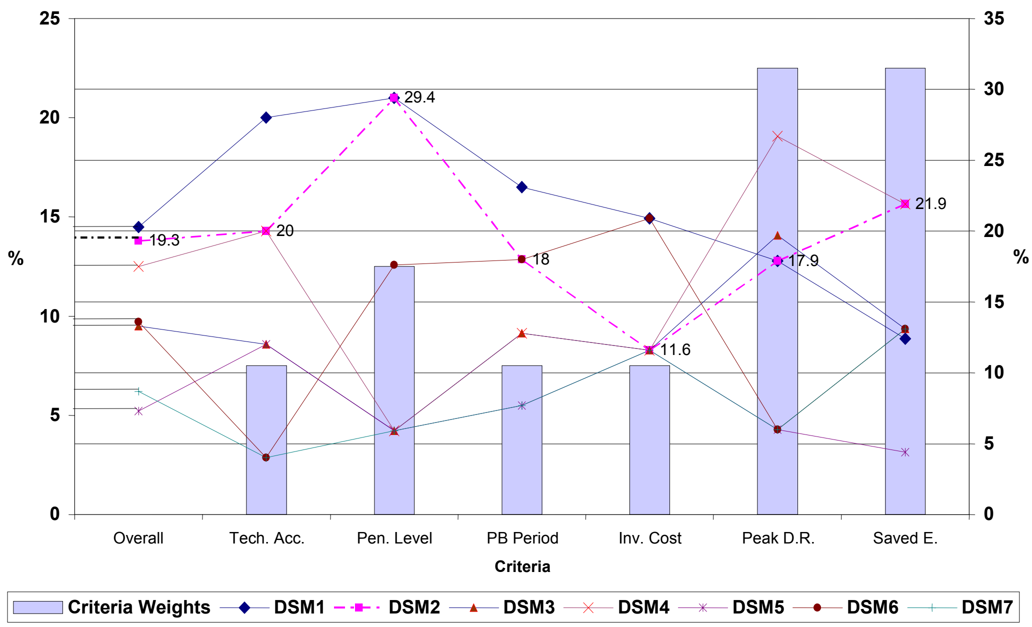
- Performance
- Dynamic
- Gradient
- Two-dimensional
- Difference

We shall use the performance sensitivity analysis to examine the sensitivity of the alternatives with respect to lower-level criteria and how this would change in the final decision.

The criteria are represented by vertical bars, and the alternatives are displayed as horizontal line graphs. The intersection of the alternative line graphs with the vertical criterion lines shows the priority of the alternative for the given criterion, as read from the right axis. The criterion's priority is represented by the height of its bar as read from the left axis. The overall priority of each alternative is represented on the OVERALL line, as read from the left axis. The original priority case (base case) is illustrated in Figure 7.4 (a).

Sensitivity analysis is then performed by modifying the weight of Saved Energy (SE) that would be achieved by efficient lighting (DSM2) from "medium" (score 5) to "high" (score 7). Keeping the criteria priorities constant, and making the necessary calculations, it was found that the final ranking of alternatives has been changed as shown in Figure 7.4 (b) and Table 7.11. The efficient lighting moved to the first priority (20.7%) with slight difference from the thermostat setting (20.1%). Priority weights of other alternatives are almost kept the same as in the base case.

Figure 7.4 (a) Performance Sensitivity Analysis
Basecase With Saved Energy Score "5" DSM 2



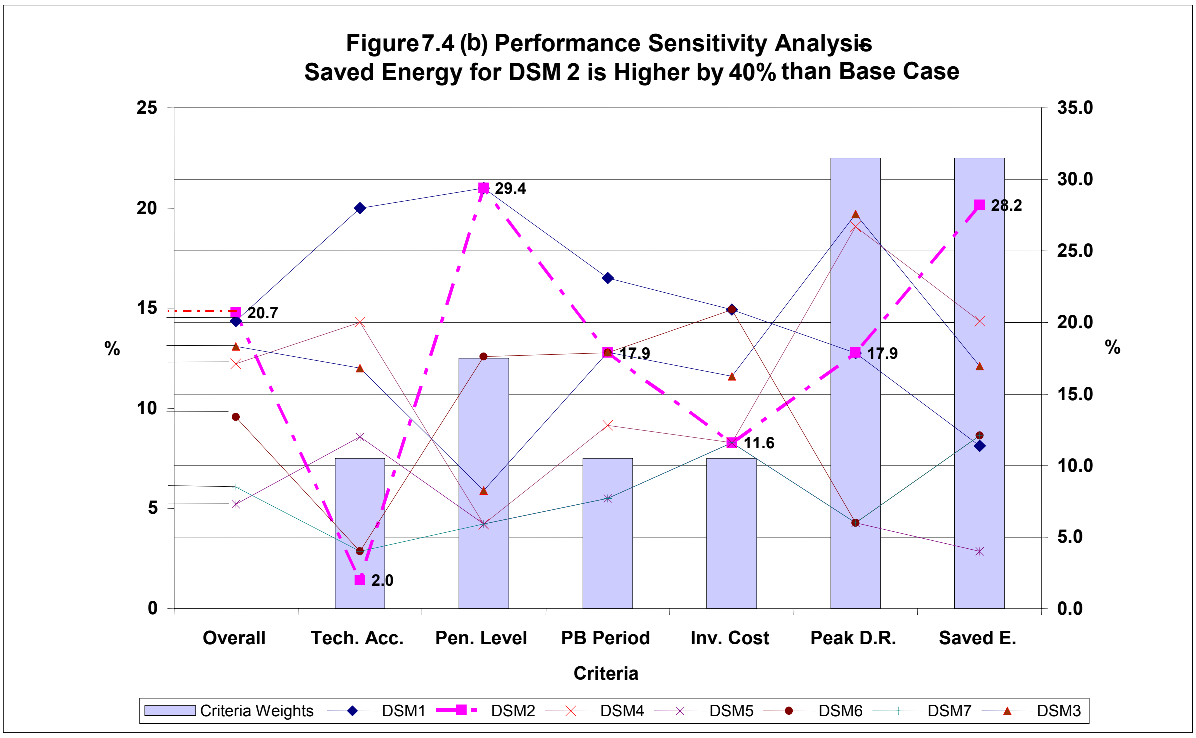


Table 7.11 - Priority Matrix for DSM Options

	SE (0,225)	PLR (0,225)	IC (0,175)	PBP (0,175)	PR (0,125)	TA (0,075)	Overall Priority Vector
DSM1	0.114	0.179	0.209	0.231	0.294	0.280	**0.201**
DSM2	0.282	0.179	0.116	0.179	0.294	0.200	**0.207**
DSM3	0.121	0.197	0.116	0.128	0.059	0.120	**0.131**
DSM4	0.201	0.267	0.116	0.128	0.059	0.200	**0.171**
DSM5	0.040	0.060	0.116	0.077	0.059	0.120	**0.073**
DSM6	0.121	0.060	0.209	0.179	0.176	0.040	**0.134**
DSM7	0.121	0.060	0.116	0.077	0.059	0.040	**0.085**

7.5 Summary

In this Chapter, the identified DSM options are analysed regarding their relative importance, features and evaluation of their priority of implementation in any future DSM programme in Kuwait. The evaluation process is complex due to the uncertainty of penetration level and market trends in the residential sector. In such complicated multi-criteria decision making process, it is required to select a reliable and intelligent tool, that is capable of comparing each DSM option and evaluate them according to multiple criteria measures.

The tool selected and applied in this Chapter for DSM evaluation and prioritization is the Analytic Hierarch Process. An illustrative example has presented to demonstrate the AHP process as applied to our case. The results of calculations have shown that the first priority of DSM programme implementation is given to the first DSM option "Increase of thermostat setting from 75 °F to 78 °F". A sensitivity analysis was performed to check the sensitivity of the final decisions to some changes in judgements. By increasing the amount of saved energy achieved by DSM2 (efficient lighting) by 40% (from score 5 to score 7), the priority of efficient lighting came to the first place.

Chapter 7 also includes a brief description and emphasizing the importance of the two recommended policy options: tariff increase and energy efficiency standards and labelling.

Chapter 8

Potential Impacts of Priority DSM Options

8.1 Introduction

The results of energy audits and simulation, discussed earlier, have shown that the identified DSM measures have a high potential of energy savings and peak demand reductions on the end-use level. The question now is how to evaluate the aggregated impacts of these measures on the residential sector level and hence on the national level in an integrated DSM programme. In this Chapter, we estimate the integrated impact of DSM options through a 10-year period of time, starting from 2010. This, of course, assumes that the preparation of any DSM programme in Kuwait has to start during the rest of this year and the beginning of 2010.

Based on the available data, it is important to answer several specific questions for realistic estimation of the DSM impacts, for example:

- How to determine the baseline demand forecast, that is the anticipated trend in energy consumption and power demand to the start of the year 2020 without any DSM activities?
- How to determine the rate of penetration of the identified technological and policy DSM options through out the sector?
- How to estimate the impacts on energy and power demands as a result of implementing each DSM option, in all types of dwellings (villas, apartments and traditional houses)?
- How to aggregate the simultaneous implementation of all DSM options, in an integrated DSM programme?

With the lack of available and up-to-date statistical data and surveys on the residential sector behaviour, we have to consider carefully several studies (relatively old) that have been conducted by KISR[43], and others.

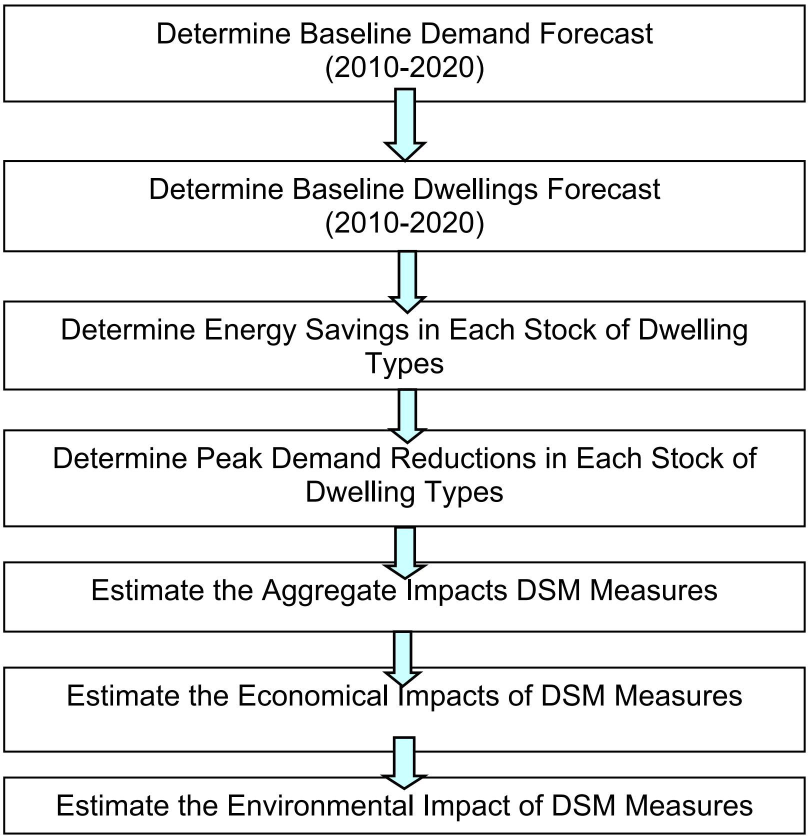
8.2 Methodology

The first step for evaluating the impacts of DSM measures on energy consumption and peak demand is to develop the baseline scenario of demand (for both energy and peak load) forecast through the 10 year planning horizon (2010-2019). The second step is to develop a forecast incorporating the current dwellings stock and the projected new constructions through the period of forecast.

In the third step we estimate the annual programme impacts, i.e., the energy savings in GWh and peak demand reductions in MW resulting from the implementation of DSM options. Impacts are developed through a building block approach that aggregates the impacts across end uses. These estimates have to take into consideration the affecting parameters such as dwelling stock, penetration rate, number and type of dwellings participating in the DSM programme and peak demand coincident factor.

The fourth step is to evaluate the economical and environmental impacts; this includes calculations of the avoided utility costs, costs of saved energy, and the associated reductions in GHG emissions (this will be presented in Chapter 9). Figure 8.1 illustrates the steps used in this methodology

Figure 8.1 – Steps of DSM Impacts Evaluation



The formula used to estimate DSM impacts is very simple, and represented as:

Achievable Potential of Energy Savings (ES) or Peak Demand Reductions (PR) = Baseline Forecast x Penetration Rate x Unit Impacts *……… (1)*

The baseline forecast is the amount of energy consumption and peak demand that would have occurred in the absence of any DSM activities. The penetration rate is the share of the market that elects to participate in the DSM programme. The unit impact is the percent reduction in energy usage and peak demand that results from the implementation of DSM option.

Achievable potential, as identified by ACEEE's research, is defined as the amount of cost-effective energy efficiency improvement expected to be captured as the result of specific policy or programme actions. This assumes that other efficiency improvements attributable to normal consumer and market behaviour, as well as other conservation policies programmes (if exist) are not neglected. This class of efficiency potential is distinguished from technical and economic potential in three important ways:

- First, as the term implies, achievable potential is defined in terms of what realistically can be captured by explicit actions.
- Second, and following from the first point, achievable potential is time-dependent. Achievable potential can be only realised by convincing consumers to replace existing equipment and practices with new, more efficient equipment and practices. It is often the case that consumers are most easily convinced to adopt high efficiency alternatives when they must make equipment replacement

Decisions anyway. Therefore, what is considered achievable potential grows over time as an increasing amount of existing equipment stock reaches the end of its useful life (assuming diffusion increases with time and the old non-efficient equipment are gradually phased out).

- Third, achievable potential intrinsically is a function of consumer behaviour. The amount of potential one might expect is based on assumptions about what consumers will do when faced with various policy and programme interventions. Because estimates of achievable potential consider this difficult-to-predict consumer behaviour, they are inherently more uncertain than estimates of technical or economical potential.

Currently, according to our knowledge, in Kuwait neither DSM programmes, nor any energy efficiency activities are now under implementation. Therefore we assume that the recommended DSM measures, in our work, will be the only achievable potential in the near future. It is very difficult to promote and implement any DSM programme in Kuwait under the current low price of electricity. For this reason, we assume that the achievable programme potential is most likely applicable with the assumption that DSM options are implemented with high incremental cost incentives. A good example of such incentive is to distribute CFLs to residential consumers with lower price (e.g. half) than its actual price.

Below we discuss the elements of formula (1).

8.3 Baseline Demand Forecast

The prerequisite step to determine energy efficiency DSM potential impacts is to establish the disaggregated baseline scenario of energy consumption and demand forecasts that is to determine the trend of energy and demand forecasts without the implementation of any DSM activity, and to establish the reference against which the impacts of DSM measures can be assessed. These load forecasts are critical inputs for the successful integration of DSM options. The forecast time horizon is 10 years, starting from 2010 to 2019 inclusive.

Currently, there are no publicly available energy consumption forecasts that include end-use sector (residential, industrial and commercial) breakdowns.

Based on the latest MEW Statistical Year Book of 2007, the development and future estimates of the installed capacity, generated energy, peak load and load factor are provided as shown in Table 8.1 for the period 2005 to 2010. The predicted values of exported energy and final energy are shown in the Table. With these trends, the average growth rates of the installed capacity, generated energy and peak load are 3.2%, 7.14% and 7.3% respectively. As shown in the Table, the growth rates of exported energy and final energy are the same and equal to 7.2%.

Back to the period 1995 – 2006, the statistical data of MEW indicates that the growth of generated energy, peak load and exported energy is as shown in Table 8.2. The average growth rate during this period was 6.6%, 5.95% and 6.9% respectively. This means that, during recent years, and up to the end of 2010, the growth rate of generated energy, exported energy and peak load are increasing which may create shortage problems in the near future.

With reference to latest information published by MEW, the peak summer load reached 8900 MW in 2006. The peak load profile occurred on 26 July 2006, illustrated in Chapter 3, Figure 3.3, and is repeated below (Figure 8.2). The peak load and extended from 14:30 to 15:30 at ambient temperature 49^{o}C and relative humidity 6%.

We will assume that these growth rates are kept constant till the end of the forecast period (2019 inclusive). Energy and power demand forecast (baseline scenario) is shown in Appendix 8.1. The Appendix shows also the forecast of both exported energy and final energy consumption. The exported energy is obtained form the generated energy by extracting the energy consumed in the power plants (MEW – 2007), and the final energy consumption is obtained from the exported energy by extracting the Transmission and Distribution (T & D) losses, which is estimated as 12%[37]. As shown in Appendix 8.1, the projected final energy consumption at the end of 2019 accounts for 89057 GWh and the projected peak demand may reach 20607 MW that is exceeding the projected planned installed capacity by more than 3140 MW, which will create a critical problem of shortage.

Table 8.1 Development of Energy and Power Demands from 2005 to 2010

Year	2005(*)	2006(*)	2007(**)	2008(**)	2009(**)	2010(**)	Growth Rate (2005-2010)
Installed Available Capacity (MW)	10189	10229	10655	11082	11736	11914	**3.2%**
Generated Energy (GWh)	43734	47605	48761	53476	58011	61660	**7.11%**
Exported Energy (GWh)	37906	41750	42422	46524	50470	53644	**7.2%**
Final Energy ((GWh)	33357	36582	37331	40941	44413	47207	**7.2%**
Peak Load (MW)	8400	8900	9070	10000	10680	11950	**7.3%**
Annual Load Factor (%)	59,4	61,1	61,4	61,0	62,0	58,9	**-0,13%**

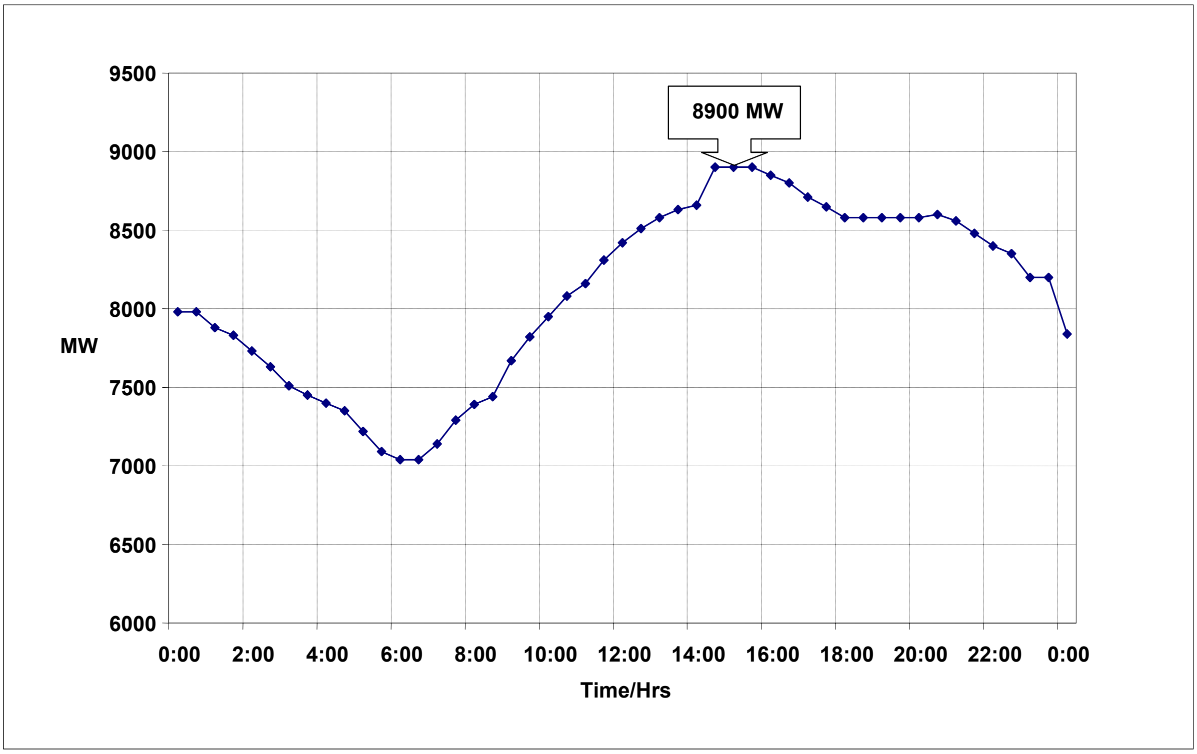
Source: MEW, Statistical Year Book, 2007
(*) Actual values
(**) Values estimated by MEW

Table 8.2 Development of Generated Energy and Peak Load (1995 – 2006)

Year	Generated Energy (GWh)	G. Rate (%)	Peak Load (MW)	G. Rate (%)	Exported Energy (GWh)	G. Rate (%)
1995	23724		4730		20266	
1996	25475	7.4	5200	9.9	21735	7.3
1997	26724	4.9	5360	3.1	22860	5.2
1998	29984	12.2	5800	8.2	25753	12.7
1999	31576	5.3	6160	6.2	26962	4.8
2000	32323	2.4	6450	4.7	27463	1.9
2001	34299	6.1	6750	4.7	29273	6.6
2002	36362	6.0	7250	7.4	31053	6.1
2003	38577	6.1	7480	3.2	33086	6.5
2004	41257	6.9	7750	3.6	35632	7.7
2005	43734	6.0	8400	8.4	37906	6.4
2006	47605	8.9	8900	6.0	41570	10.1
Average		**6.6**		**5.95**		**6.9**

(*) Equal to generated energy minus energy consumed by power plants.

Figure 8.2 - The Peak Load Profile "26 July, 2006"



8.3.1 *Demand Forecast for Residential Sector*

Unfortunately, recent data for the distribution of energy consumption by sector is not available. Based on a study published by the World Bank in 1993, the consumption of residential sector in 1989 was estimated at 63% of total consumption. Industrial sector had a share of 20%, followed by the government with 10% and commercial sector with 8%. Later, in 2002, articles published through KISR (Aasem, and others, DBET) estimated the distribution of electricity consumption by sector as illustrated in Table 8.3.

Between 1970 and 2001, the share of residential consumption had been increased from 55% to 65% due to improved housing and higher per capita income, which resulted in increased usage of central air conditioning and other appliances. It can reasonably be assumed that residential consumption has continued to rise over the past decade, as a consequence of further improved housing and higher space.

As a conservative approach, and due to the lack of up-to-date information about the trend in residential sector consumption, we will assume, in our analysis, that the share of residential consumption is kept constant at 65% of total consumption through out the period of forecast.

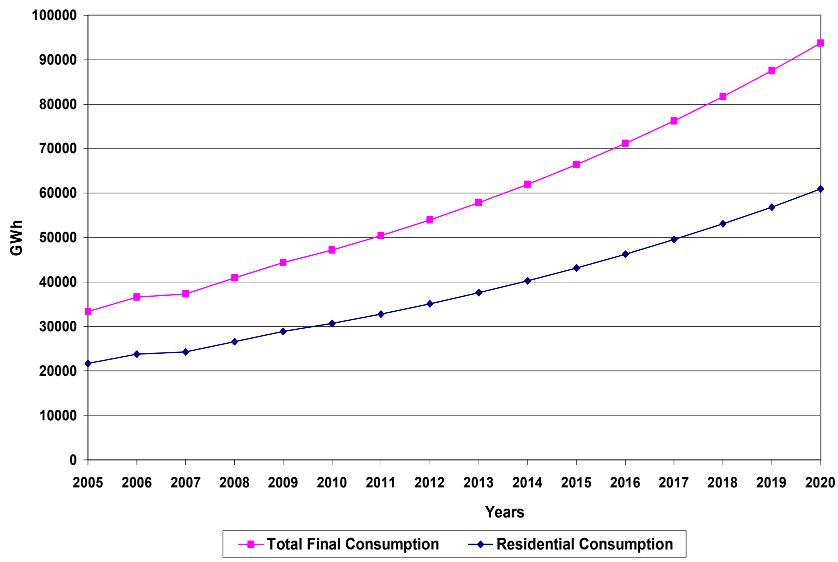
Table 8.3 Electricity Consumption by Sector in %

Year	Residential	Governmental	Industrial	Commercial
1970	55	11	24	10
1989	63	10	20	8
2001	65	11	16	8

Sources: World Bank: A Privatization Strategy for Kuwait 1993 and KISR 2002

Figure 8.3 shows the baseline demand forecast for both final energy consumption and residential consumption.

Figure 8.3 Baseline Forecast for Electricity Consumption (Total Final and Residential)



8.3.2 *Housing Forecast*

Housing stock and forecast are basic prerequisites for the evaluation of DSM impacts. It should include the present existing stock of each type of dwellings (villas, apartments and traditional houses), as well as the projected new constructions through the period of forecast (2010 – 2020).

With reference to the Annual Statistical Abstract of 2007, published by the Central Statistical Office of Kuwait, the results of the three buildings censuses performed in 1985, 1995 and 2005 are summarized in Table 8.4. The number of private buildings has been increased from 102,510 in 1985 to 119,856 in 1995 to 165,029 in 2005, with an annual growth rate approximately 3.1%. The total number of dwellings estimated through the three censuses is: 213,591 in 1985, 234,153 in 1995 and 303,045 in 2005. The classification of these dwellings is available only in 1985 census as follows: 40,689 villas, 110,252 apartments, 33,106 traditional houses and 6,773 others. Some efforts were made during the 90s for estimating the number of each residential type. Taking into consideration these estimates and the available number of buildings in 2005, the approximate dwellings stock could be estimated as:

- 104650 Villas (35%)
- 122666 Apartments (40%)
- 36500 Traditional houses (12%), and
- 40229 Other (13%)

Other dwellings are mostly low-income dwellings, and will be excluded from the forecast.

According to the Annual Statistical Abstract of Kuwait, the number of new construction permits in 2006 and 2007 were 9957 and 11169 respectively, representing about 6% and 6.4% of total residential buildings. On the other hand, the rate of new dwellings construction (Villas, traditional houses and apartments), announced by the Public Authority for Housing Welfare (PAHW), is approximately 3% per year. Interviews with technical staff in the MOP indicated that approximately, the same percentage is added every year by dwellings construction through private companies. Therefore, the total additions of dwellings every year could be assumed 6% of the existing stock.

Due to the unavailability of data on the exact numbers of future dwellings construction classified by type, we will assume that the number shared by each dwelling type is kept constant all-over the forecast period. This assumption is more conservative with respect to DSM impacts, since the trend in Kuwait is to own/live in villas (associated with higher consumption) than traditional houses and apartments.

Also, it was assumed in the Analysis that the demolition rate is negligible.

Table 8.4 – The Development of Private Buildings Stock

Census	1985								
Type of Building	Villa	%	Apartment	%	Tr. House	%	Other	%	Total
No. of Buildings	53839	52,5%	9959	9,7%	33670	32,8%	5042	4,9%	**102510**
Households	42323	19,1%	112448	50,7%	36358	16,4%	30642	13,8%	**221771**
Census	**1995**								
Type of Building	Villa	%	Apartment	%	Tr. House	%	Other	%	Total
No. of Buildings	61870	51,6%	9862	8,2%	30969	25,8%	17155	14,3%	**119856**
Households	Na		Na		Na		Na		
Census	**2005**								
Type of Building	Villa	%	Apartment	%	Tr. House	%	Other	%	Total
No. of Buildings	104650	63,4%	13579	8,2%	31000	18,8%	15800	9,6%	**165029**
Households	Na		Na		Na		Na		**307285**

Source: Annual Statistical Abstract, Edition 44, 2007, Kuwait.

8.4 Penetration Rate of DSM Options

To estimate the achievable DSM potential, it is important to apply market penetration rates (PR) to the technical potential estimates. In general, the penetration rate of any DSM measure is uncertain and related to market conditions, end-use technology, extend of cost sharing required by the consumer, the level of economic awareness, customer acceptance and preference. However, one feasible method to deal with uncertain circumstances is, for the experts in the field, to identify the most likely scenarios based on their experience and available economic and technical data.

In our analysis the diffusion of DSM measures into the market and its adoption by customers will be subject to the following assumption:

8.4.1 *Market Transformation*

While no single definition exists, market transformation generally refers to the process by which collective action, policies and programmes effect a positive, lasting change in the market for energy efficient technologies and services, such that these

Technologies and services are produced, recommended and purchased in increasing quantity, (Suozzo and Nadel, 1996)[44].

The essential role of market transformation programme, through DSM, is to accelerate the adoption of energy efficient technologies and practices, resulting in market transformation, or lasting change in the structure of the market, such adoption of energy efficient technologies become normal or standard practice[45].

To simulate the growth of energy efficiency DSM options market share over time for the projected programme driven, we apply the simple logistic equation represented by:[46,47]

$$Y_t = \frac{k}{1 + e^{-b(t - t_m)}} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (2)$$

where, Yt is the market penetration in year t; k is the maximum market penetration, or saturation level; b is the penetration or diffusion rate; and t_m is the time required to reach 50% of the saturation level and is the inflection point in the logistic curve.

Equation 2 produces the familiar S-shaped curve. The penetration rate b specifies the "width" or "steepness" of the curve (e.g., b=0.19 means approximately 19% growth per time fraction). The logistic model is symmetric around the midpoint t_m . The parameter k, as discussed, is the asymptotic limit that the growth curve approaches, i.e., market niche saturation.

In our analysis, we assume that the DSM technologies will compete with the existing technologies according to the logistic formulation represented by Equation 2. For example, in case of high efficiency lighting (DSM2), the CFL or LED lamps will compete with the conventional incandescent lamps, through the DSM programme.

To implement this approach for appropriate adoption of DSM measures, it is required to estimate suitable values of penetration rate taking into consideration market conditions in Kuwait and expected barriers. Low penetration rates (less than 5%) are

Expected particularly in the early stages of any DSM programme, even with full support from the government.

For example, the experience of the European Union in high efficiency lighting, mainly the penetration of CFL, has shown that the penetration of CFL to the market is on average less than 5% and in the households that owned CFLs is a bit above 10% (based on 1995 data)[48].

Given that the diffusion function employed is not directly linked to measure or programme economies, we exercise judgment in selection parameter values that reflect market condition and energy efficiency trends in one hand, and new DSM programme intervention that would yield achievable potential on the other.

Figure 8.4 illustrates an example of S-curve representing the rate of adoption of four DSM options. For the existing dwellings, the values of penetration rate "b" are assumed as follows:

a) For DSM1 and DSM2 (see note) we assume that 80% saturation represents full adoption of the two options by the year 2030. The other 20% are not willing to participate.

We assume also that by the year 2020 only 50% of the fully adopted residential consumers have implemented the two options. The promotion and implementation of DSM1 depend mainly on the effectiveness of program publicity. No hardware is required for this option; it is only required to convince the consumer to increase thermostat setting from 75˚ F or less, to 78˚ F determined by ASHRAE as a comfortable level.

For DSM2, it was assumed that 80% of the installed conventional incandescent lamps would be replaced to CFL, as indicated by simulation process. This technology has been experienced with many countries, and has been the target of a number of energy efficiency programs. Given the nature of the market diffusion process, market share growth tends to be most rapid relatively early in the market life of the technology if it offers compelling market advantages and/or if it is heavily subsidized. Media will play an important role to achieve higher levels of market penetration.

b) For DSM3 and DSM5, the use of efficient A/C equipment, and more efficient end-use equipment (refrigerators, washing machines, water heaters, etc.), we assume that only 20% of the saturation level could be adopted by the year 2020. We assume also that the policy option DSM7, application of Labels and Standards, is combined with DSM5. Both options are aiming to the use of more efficient end-use equipment.

c) The penetration rate of the four DSM options, mentioned above, will be assumed to be adopted by 20% of the new dwellings. The rest (80%) will be added to the existing buildings that are subject to market behavior.

d) DSM4, the use of light colored roof and wall with high level of insulation: Is assumed to be applied only for new buildings, with penetration rate fixed at 20%.

e) DSM6, tariff increase:

The impact of tariff increase on energy consumption is a difficult process particularly in the condition of Kuwait, since the tariff has not been increased in nominal terms for over thirty years, although the MEW has considered tariff increases since the early 1980's. In September 1999, a new tariff proposal was submitted by the MEW. Under a 1995 law, the government has to seek parliamentary approval when it comes to increasing changes. The tariff proposal thus has to be approved by the Council of Ministers and National Assembly. According to our knowledge, it is not yet clear whether the approval would be granted. The expected effect of the tariff increase on energy conservation cannot be quantified by MEW.

The proposal comprises a four-tier tariff for residential consumers [37] (private houses and apartment buildings) with a rising block structure (four blocks each), and different tariffs for commercial, governmental and industrial consumers and for beach cabins.

The rise in the electricity tariffs represents increases by 100% to 400%, depending on the consumer category. Private consumers will face price increases by 125% on average, while charges for the government, commerce and industry will be raised by 150% to 400%. The proposed new tariff is shown in Table 9.5.

Table 8.5 Proposed New Electricity Tariff

Consumer Category	Current Price (Fils/kWh)	Proposed Price (Fils/kWh)	Price Increase (%)
Private Houses	2	4.5	125%
Beach Cabins	10	10	0%
Commercial & Governmental	2	10	400%
Industrial & Agricultural (Shuaiba)	1	5	400%
Industrial & Agricultural (Other)	2	5	150%

The tariff for apartment buildings is differentiated according to the metering: consumers in apartments with separate meters (one for A/C and one for other uses) are charged differently than consumers in apartments with central meters for A/C. The latter pay different tariffs for non-cooling demand and for A/C (to be apportioned by the building owner).

The maximum tariff of 10 Fils is paid for monthly consumption above 6000 kWh in apartment buildings with separate meters, while consumers in private houses have to pay this tariff only for consumption above 12000 kWh, as illustrated in Table 8.6.

Table 8.6 Proposed New Electricity Tariffs for Residential Consumers

	Private House	Apartment Building			Current Price (Fils/kWh)	Proposed Price (Fils/kWh)	Price Increase (%)
		Separate Meters	Sep. Meters for Non-A/C	Central A/C Meters			
Consumption Block from kWh to kWh	1-6000	1-1500	1-600	1-900	2	2	0%
	6001-9000	1501-3000	601-1200	901-1700	2	4	100%
	9001-12000	3001-6000	1201-2400	1701-3600	2	6	200%
	>12000	>6000	>2400	>3600	2	10	400%
	Average				**2**	**4.5(*)**	**125%**

(*) Average based on the assumption that 70% of the consumers are in the lower two consumption brackets which pay an average price of 3 Fils/kWh, and that 30% pay an average of 8 Fils/kWh.

Since the tariff increase will multiply the present household expenses for electricity, the proposal faces strong opposition from the consumers who have been used to low electricity prices for more than a generation. The new tariff proposal, however, takes into account equity considerations: In the lowest consumption bracket the tariff remains unchanged. Assuming that a large share of the consumers falls into these brackets, only the consumers with high consumption will be affected, who typically are consumers with higher income. Thus it may be assumed that the tariff increase will mainly affect the consumers who

(a) Can afford higher tariffs, and
(b) Have a high savings potential.

KISR Study on Tariff Effect

KISR study on tariff increase was conducted in 1987[49], to assess the impact of alternative electricity tariffs with regard to electricity conservation, equity for consumers and profitability for producers, government subsidy and macro-economic effects. The study was only concerned with the energy savings impact and did not estimate the effect on the peak load.

According to KISR study, the average residential consumption was 40,507 kWh in 1984; the richest 10% of the households consumed about twice the average amount, while the poorest consumed 75% of the average. Specific consumption more than doubled between 1972/73 and 1984, and the average budget shares of electricity decreased by 50% from 1.2% to 0.67%. Electricity expenses represented 2.1% of total household budgets of the poorest 10% and 0.4% of the richest 10% of consumers.

In KISR study, a combination of time series and cross section data sets were used to estimate demand functions for residential consumption. Cross section data was used to estimate the income elasticity of demand, while the time series data served to estimate the price elasticity of demand. Short term price elasticity was found to be in the range of -0.09, and the medium run price elasticity (two to five years) in the order of -0.30.

Table 8.7 shows the savings potential of tariff increase according to KISR study conducted in 1987. Five tariff scenarios were tested, comprising three or four increasing blocks between 0 and 7,500 kWh/ month with tariff between 2 and 28 Fils/kWh. In addition two scenarios with a two-tier multi-tariff system (for two different housing types) and rising block structure (over three blocks) were tested, and with 12 Fils/kWh as the highest tariff, as proposed by MEW, and one with 28 Fils/kWh as the highest tariff.

Table 8.7 Savings Potential of Tariff Increase According to KISR Study

Scenario	Price Elasticity -0.09				Price Elasticity -0.30			
	Avg. new Price (Fils/kWh)	Avg. Price Increase	Avg. Consum. Reduction	Computed Elasticity	Avg. new Price (Fils/kWh)	Avg. Price Increase	Avg. Consum. Reduction	Computed Elasticity
A	5.6	180%	-5.6%	-0,031	5.66	183%	-19%	-0.104
B	5.76	188%	-7.7%	-0,041	5.76	188%	-26%	-0.138
C	6.10	205%	-6.9%	-0.034	6.11	206%	-23%	-0.112
D	7.3	265%	-14.9%	-0.056	7.30	265%	-49%	-0.185
E	7.5	275%	-10.6%	-0.039	7.50	275%	-35.3%	-0.128
F1	4.10	105%	-5.1%	-0.049	4.10	105%	-17.5%	-0.167
F2	2.95	48%	-4.0%	-0.084	2.95	48%	-13.5%	-0.284
G1	8.6	330%	-11.0%	-.033	8.60	330%	-36.8%	-0.112
G2	5.27	164%	-9.8%	-0.060	5.27	161%	-33%	-0.206

Source: KISR, "The Economic Impact of Changing the Structure of Electricity Pricing in Kuwait, Final Report, June 1987.

According to the results of the study, the reduction potential of tariff increase was between 4% and 15% under the assumption of price elasticity of -0.09, and between 14% and 49% under the assumption of a price elasticity of -0.30, depending on the tariff scenario as shown in Table 9.7. The reported results, however, are not consistent with the assumed price elasticity. An average reduction in consumption by

5.6%, following an average price increase by 180% (as in the tested scenario A) representing price elasticity of (-5.6%/180% =) -0.031 instead of the explicitly assumed elasticity of -0.09, as shown in the table above.

Thus, we may conclude that the short run prices elasticity were rather in the range of -0.03 to -0.06, and the medium run elasticity in the range of -0.10 to -0.20. These prices elasticity seem to be more realistic than the explicitly assumed price elasticity of -0.09 and -0.30 respectively, for the following reasons:

- The actual impact of a tariff increase is determined by the general income level and by the extent of the increase.
- Studies have shown that studies have a considerable impact on energy use in countries where income is still low, but have a low impact on countries where income is relatively high, because in these countries, like in Kuwait, expenses on electricity have only a marginal share in the household budget. The price elasticity of residential consumers in Kuwait is, therefore, expected to be rather on the low side,
- Studies on prices elasticity generally refer to percentage increases of the electricity tariff in the range of 1% to 50%, not to a doubling or tripling of the tariff. When, as proposed in Kuwait, the tariff is increased by 100% to 400%, electricity demand cannot be expected to react according to the standard price elasticity: assuming a short run price elasticity of -0.10, a tariff increase by 400% would theoretically result in an immediate reduction of demand by 40%, which is highly unrealistic, giving the technical restraints in short term energy savings in Kuwait.

Based on the above background, we use in our analysis, two scenarios; one with an average short term elasticity of -0,04 and a minimum medium term (five years) price elasticity of -0.10. The price increase will be as proposed by MEW, i.e. with an average price increase for residential consumers is in the range of 125%. Under the above assumption, the energy consumption of the residential consumers will decrease as a result of the price increases by 6% (125%*-0.04) and 15% (12.5% * -0.10), respectively, over the period of forecast.

Peak demand reductions, associated with energy conservation, due to tariff increase is hard to estimate. Since the average load factor is usually decreased due to the reduction in energy consumption, we will assume that the peak load is reduced by, at least, 1% and 2% for the short and medium term elasticity respectively. These minimum impacts of tariff increase on peak demand are taken as a conservative approach. Table 8.8 summarizes the impact of tariff increase on energy consumption and peak load considered in our calculations.

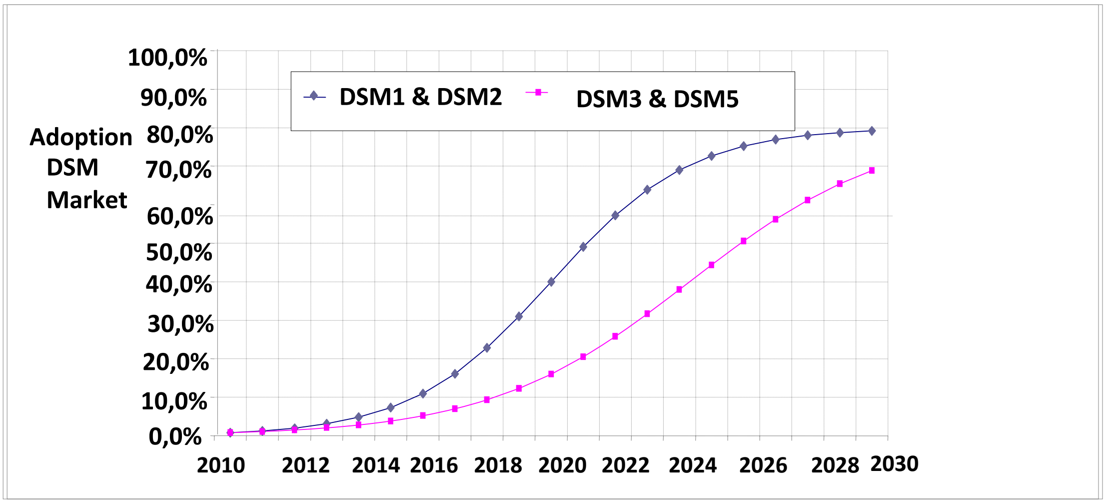
Table 8.8 Assumptions for the Potential Impact of Tariff Increase on Energy and Load

Scenario	Assumed Elasticity	Average Price Increase	Reduction in	
			Energy	Peak Load
Scenario 1	Short term : 0.04	125%	5%	1%
Scenario 2	Medium term: 0.10	125%	12.5%	2%

On the other hand, we assume, in our analysis, that the government will enhance adoption of recommended DSM options through positive incentives such as:

- Cost-sharing arrangements, in such a way that a considerable portion of the initial cost is provided by MEW, so that the payback period for the residential consumer is equal to or less than two years.
- The DSM programme cost is fully paid by the government.
- Information campaigns supported by the government.

Figure 8.4 Logistic S-Curve DSM Market Adoption



8.5 Unit Impact

The Unit Impact is the percent reduction in energy usage and peak demand that results from the implementation of the DSM option. It will be assumed that all types of dwellings adopted in the DSM programme are typical as that considered in the simulation process. For a wide range of buildings, this assumption suffers from in-accuracy. However, we assumed that the samples selected for energy audits and simulation are most likely represent the majority of typical dwellings. Actually, energy consumption in each type of dwellings is diversified. Accepting this diversity, our assumption could reasonably represent the average patterns of energy consumption of dwelling stock. Thus, the unit impacts of energy savings and peak demand reductions used in our calculations will based on the results of simulation shown in Tables 6.3, Chapter 6.

8.6 Cumulative DSM Impacts

The next step is to aggregate measure savings potential resulting from the logical groups or bundles. This grouping exercise is important in fully integrated resource planning because individual option savings are generally not large enough to weigh against supply-side alternatives. The idea is to give the options enough critical mass so that they can be selected by the resource planning model[50].

Table 8.9 (A and B) displays the DSM impacts pertaining to the potential annual energy reduction that could be achieved for each type of dwelling. Potential energy savings from villas are more significant than that from apartments and traditional houses. Table 8.9 (a) shows the results of calculations for the scenario of tariff price elasticity of -0.04, while Table 8.9 (b) shows the scenario of tariff price elasticity of -0.1. For the second scenario, the total potential of energy that could be saved by the end of 2019 is approximately 4263 GWh, representing about 10.2% of total residential consumption and about 4.96% of total end-use energy consumption. The accumulated sum of the potential energy savings across the forecast horizon may reach 37229 GWh, representing approximately 67% of the generated energy in the base year 2010 (see Table 8.9 (b).

Table 8.9 (a) DSM Impacts by Type of Dwelling - Annual Energy Savings (GWh) (Scenario 1: Tariff Price Elasticity -0.04)

Year	Villas	Apartments	Tr. Houses	Total	% Residential	% Final En. Consumption
2010	871.2	275.8	170.3	1317.3	4.79%	**2.79%**
2011	850.7	267.9	166.0	1284.7	4.46%	**2.55%**
2012	867.5	271.9	169.1	1308.6	4.33%	**2.42%**
2013	895.7	279.5	174.5	1349.7	4.26%	**2.33%**
2014	929.9	288.9	181.0	1399.8	4.22%	**2.26%**
2015	978.7	302.8	190.3	1471.9	4.23%	**2.22%**
2016	1048.2	323.0	203.7	1574.9	4.32%	**2.21%**
2017	1127.3	346.0	218.9	1692.1	4.43%	**2.22%**
2018	1218.9	372.6	236.5	1828.0	4.57%	**2.24%**
2019	1313.2	399.8	254.6	1967.5	4.69%	**2.25%**
Total	**10101.3**	**3128.4**	**1964.8**	**15194.5**		

Table 8.9 (b) DSM Impacts by Type of Dwelling - Annual Energy Savings (GWh) (Scenario 2: Tariff Price Elasticity -0.10)

Year	Villas	Apartments	Tr. Houses	Total	% Residential	% Final En. Consumption
2010	2071.1	661.4	406.2	3138.7	11.41%	**6.65%**
2011	2300.0	731.4	450.7	3482.1	12.08%	**6.91%**
2012	2326.3	736.2	455.4	3517.9	11.64%	**6.52%**
2013	2364.1	744.6	462.3	3571.0	11.28%	**6.17%**
2014	2408.0	754.9	470.4	3633.2	10.95%	**5.86%**
2015	2466.6	769.6	481.3	3717.5	10.69%	**5.60%**
2016	2545.9	790.6	496.3	3832.8	10.52%	**5.39%**
2017	2634.9	814.4	513.1	3962.4	10.37%	**5.20%**
2018	2736.5	841.8	532.4	4110.7	10.27%	**5.03%**
2019	2840.9	869.8	552.1	4262.8	10.16%	**4.87%**
Total	**24934.2**	**7791.9**	**4867.3**	**37229.1**		

Table 8.10 (a) and Table 8.10 (b) display the DSM impacts pertaining to peak summer demand reductions that have been developed through simulation and assumed impacts of tariff increase with the first scenario of elasticity -0.04 and second scenario with elasticity -0.1 respectively. By the year 2020 the aggregate sum of peak demand

reductions is estimated at 1245 MW and 1530 MW for the first and second scenarios respectively, representing about 7.3% and 8.9% of the overall summer peak.

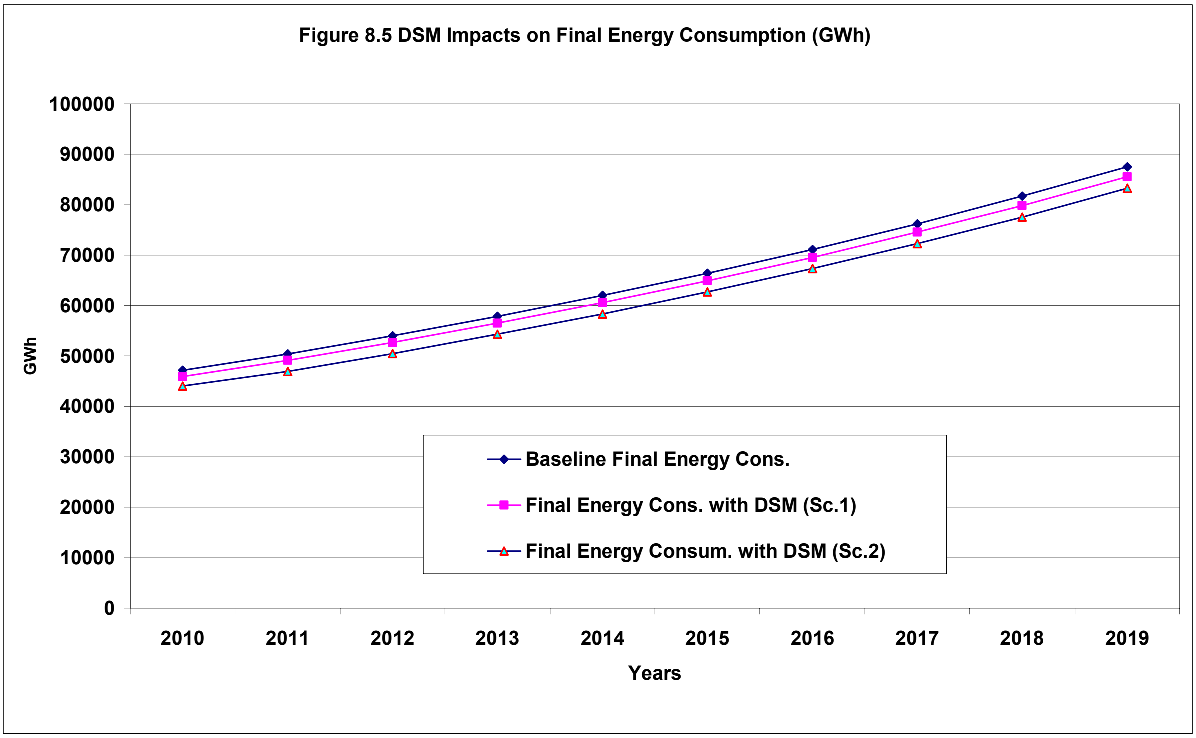
Table 8.10 (a) DSM Impacts by Type of Dwelling - Peak Demand Reductions (MW) - Scenario 1: Tariff Elasticity – 0.04

Year	Villas	Apartments	Tr. Houses	Total	% Of Overall Peak Load
2010	113.3	190.1	34.6	338.0	**3.1%**
2011	109.6	183.8	33.7	327.2	**2.9%**
2012	120.4	201.9	37.4	359.6	**3.0%**
2013	136.9	229.7	42.8	409.5	**3.2%**
2014	157.9	265.0	49.8	472.7	**3.6%**
2015	187.4	314.5	59.7	561.6	**4.0%**
2016	230.0	385.9	73.9	689.8	**4.7%**
2017	281.5	472.3	91.3	845.1	**5.5%**
2018	344.5	578.0	112.7	1035.2	**6.4%**
2019	413.9	694.4	136.5	1244.9	**7.3%**
Total					

Table 8.10 (b) DSM Impacts by Type of Dwelling - Peak Demand Reductions (MW) - Scenario 2: Tariff Elasticity – 0.10

Year	Villas	Apartments	Tr. Houses	Total	% Of Overall Peak Load
2010	172.4	289.3	52.7	514.4	**4.7%**
2011	171.7	288.1	53.0	512.8	**4.5%**
2012	185.7	311.6	57.8	555.2	**4.6%**
2013	205.7	345.2	64.6	615.5	**4.9%**
2014	230.4	386.5	73.0	689.9	**5.2%**
2015	263.8	442.6	84.3	790.7	**5.7%**
2016	310.5	520.9	100.1	931.5	**6.3%**
2017	366.4	614.7	119.2	1100.3	**7.1%**
2018	434.0	728.2	142.4	1304.6	**8.0%**
2019	508.4	853.0	168.1	1529.5	**8.9%**
Total					

Figure 8.5 shows the forecast of final energy consumption with and without DSM impacts. The baseline consumption of residential sector is also shown in the figure. Figure 8.6 shows the DSM impacts on summer peak demand.



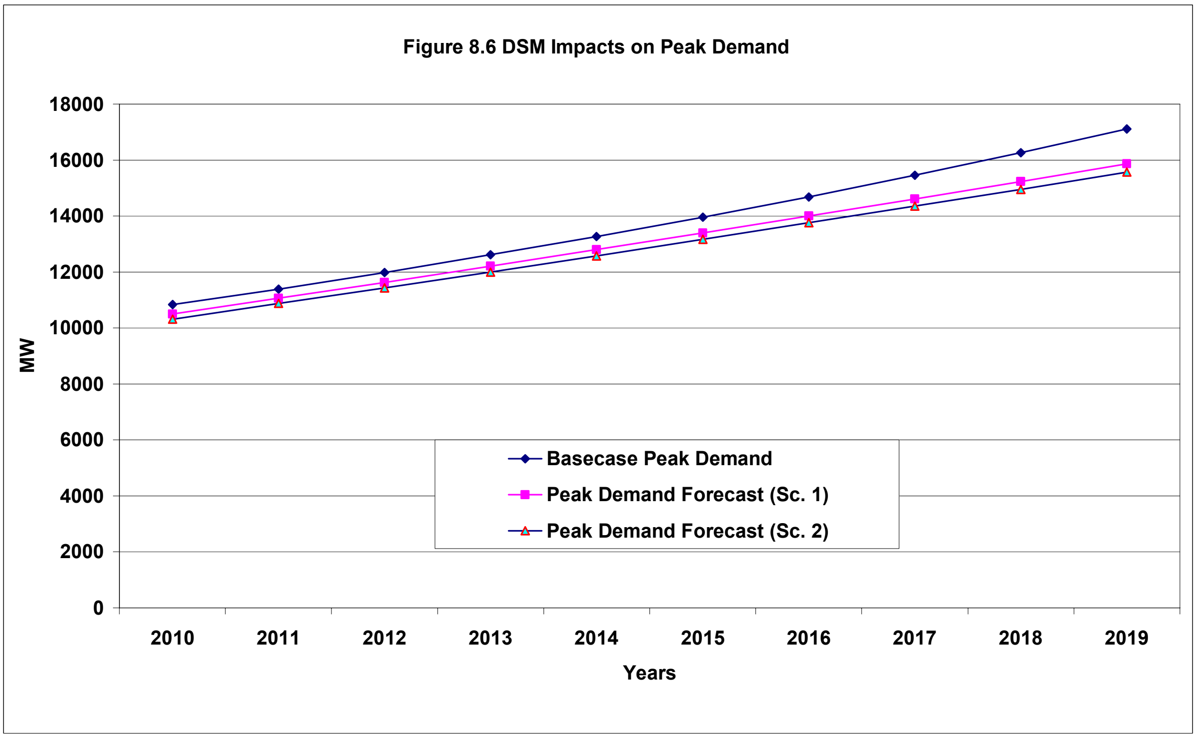


Table 8.11, displays the accumulated energy saving across the period of forecast (2010 – 2019), classified by DSM measure. From which it is clear that the impact of tariff increase (DSM6) is highly significant and representing about 90% of total DSM impacts.

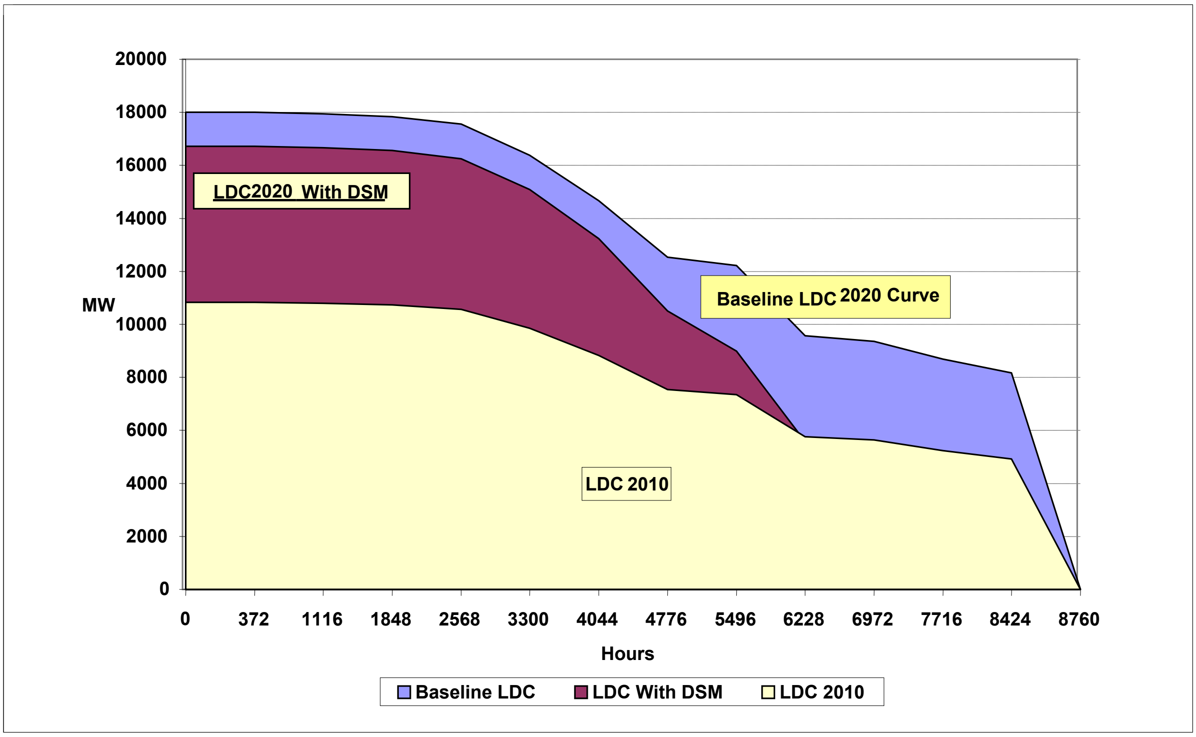
Table 8.11 DSM Energy Saving Impacts by DSM Option

Dwelling	Energy Savings (GWh)							
	DSM1	**DSM2**	**DSM3**	**DSM4 + DSM7**	**DSM5**	**DSM6 (*)**	**Total**	**Total with 0.8 D.F.**
Villas	857	906	390	66	107	20601	22927	**22462**
Apartments	256	271	111	4.4	30.2	6477	7149.6	**7015**
Tr. Houses	165	174	73.3	8.6	20.1	4031	4472	**4384**
Total	**1278**	**1351**	**574.3**	**79**	**157.3**	**31109**	**34548.6**	**27639**

D.F. = Diversity Factor
(*) With Tariff Price Elasticity -0.10

Figure 8.7 shows the Load Duration Curve (LDC) for the base year 2010 and the expected LDC for the year 2019 - inclusive with and without DSM impacts. The reduction in peak demand in the terminal year 2020 is 1530 MW. The saved energy at the start of 2020 is shown by the blue area of the curve.

Figure 8.7 the Impact of DSM Options on Load Duration Curve



8.7 Summary

Chapter 8 provides estimates for the potential energy savings and peak demand reductions resulting by the implementation of identified DSM measures. A building block approach was used to estimate the aggregate impacts of DSM options. Estimates based on this approach resulted in several potential indicators related to energy savings and peak demand reductions:

- By the end of forecast period (2010 – 2019 "inclusive"), the projected aggregate savings in energy consumption may reach 4263 GWh representing about 10.2% of the total residential consumption, and the peak demand reductions may reach 1530 MW representing 8.9% of the overall peak load.
- The total accumulated energy savings across the forecast period was estimated at approximately 37229 GWh through the whole DSM programme.
- The tariff increase, or DSM6, has significant potential in reducing growth in Kuwait energy consumption, where the achievable potential accounting for about 90% of total DSM impacts, for a price elasticity -0.10.

The next step is to estimate the potential financial and environmental impacts associated with the implementation of DSM measures. This will be discussed in Chapter 9.

Chapter 9

Economical and Environmental Impacts

9.1 Introduction

In Chapter 8 the potential achievable impacts of the identified priority DSM options were estimated in the form of energy savings in GWh and peak demand reductions in MW.

In this Chapter, the economical and environmental impacts of the identified DSM measures are evaluated through the implementation of a DSM programme executed from 2010 to 2020 and initiated by the MEW of Kuwait. A number of specific questions are addressed in the present Chapter, including:

- What is the cost of saved energy (CSE) for each DSM option?
- What are the revenues achieved by saving energy / power?
- How the cost-effectiveness for each DSM option is evaluated?
- What is the amount of CO_2 reductions that could be achieved by the implementation of DSM options?

The Chapter includes the basic formulas used for calculations, economic assumptions, the methodology used for calculations, as well as models of spread sheets used for calculations.

9.2 Economic Benefits/ Cost Analysis

Economic screening, which follows the identification of DSM technologies and the assessment of their technical potential, as presented in Chapter 8, is the main determinant of a measure's acceptance or rejection. It entails an analysis of the costs and benefits associated with each of the selected DSM measures. Benefits are typically calculated from marginal costs of energy and capacity. Cost/benefit analysis can be carried out in many degrees of detail.

Cost/benefit analysis of DSM measures has been discussed in many studies and publications. DSM measures are evaluated in these studies either as self sustained energy conservation technologies or as a part of Integrated Resource Planning (IRP) (UNEP, 1997)[51].

Most of these studies use a common approach involving screening the potential DSM measures by comparing each measure's ***Cost of Saved Energy (CSE)*** and ***Cost of Saved Capacity (CSC)*** with ***the avoided energy and capacity costs***[52]. Measures for which the CSE and CSC exceed the avoided energy and capacity costs are rejected because any such DSM measures are more expensive than supply-side alternatives. Measures for which at least one of these two values is less than the corresponding avoided cost are retained to form the basis for a DSM programme. Programme design specifies how some combination of measures will be marketed, delivered to customers, tracked, and evaluated. The process of building up programmes around DSM measures is outside the scope of this work.

In the next sections, we introduce briefly the basic definitions of avoided cost, the CSE and the CSC. These definitions are given in details in Appendix 3 of Reference 1 (UNEP 1997).

9.2.1 *Avoided Cost*

From the perspective of resource economics, the value of DSM is measured by the electricity supply costs that would be required without the DSM savings to electricity use. These supply-side costs are collectively referred to as "avoided costs". One key element of the avoided cost is the capital costs of electric generating plant. Other elements of avoided cost include:

- Plant operation and maintenance (O & M) costs.
- Fuel costs.
- Transmission and distribution (T & D) costs.

In Kuwait, official up-to-date information from MEW about the avoided energy and capacity costs are not available, however, several technical papers and studies conducted by the staff of KISR considered the following cost estimates for their analyses[6,53,54]

- **Avoided Energy Cost:**[53]

As mentioned in Chapter 3, the actual cost of producing each kWh has been estimated in the range of 14 to 26 fils, while the residential consumer pays a flat rate of 2 fils/kWh (≈ US¢ 0,6). That is there is a subsidy of 12 to 24 fils/kWh.

In our analysis, the minimum avoided energy cost (14 fils/kWh) will be considered.

- **Avoided Capacity Cost:**[6,8,9,54]

For the nation, the cost of power equipment, transmission and distribution, is around KD 400/kW. On the other hand MEW charges the consumer for cable connection KD 50 per kW. In our calculations, KD400/kW ((≈ US1200/kW) will be assumed.

9.2.2 *Cost of Saved Energy (CSE)*

The CSE is defined as the *annualized incremental cost of the DSM measure relative to the cost of standard equipment, divided by the annual kilowatt-hour saving.*

In other words, the CSE is the sum of net annualized capital costs of an efficiency DSM measure and its net increase (or decrease) in operating costs, divided by the annual energy savings:

$$CSE = \frac{ALCC}{D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

CSE = Cost of saved energy (e.g., $/kWh)
ALCC = Modified annualized life cycle cost (e.g., $/year) of the DSM measure: this cost should not include savings from reduced energy consumption,
D = Annual energy savings (e.g., kWh/year)

The formula of the CSE can usually be simplified by assuming that the energy savings are a uniform annual series, in which case:

$$CSE = \frac{(CRF \cdot Cc + Cop)}{D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where

CRF = Capital Recovery Factor

$$= \frac{r}{[1-(1-r)^{-t}]} \qquad \text{.............................(3)}$$

Cc = Capital cost of measure ($)
Cop = Operating cost of the measure only ($/year) (do not include any energy savings)
D = Annual energy savings
r = discount rate
t = equipment lifetime

9.2.3 *Cost of Saved Capacity (CSC)*

The CSC is an important parameter for the evaluation of peak reduction, and thereby delaying the need for supply capacity expansion, rather than energy consumption. CSC is defined as:

$$CSC = \frac{LCC^{*} \,.\, (8760 \text{ hr/yr}) \,.\, LF}{D} \qquad \text{.................. (4)}$$

where,
CSC = Cost of saved capacity ($/kW)
LCC* = Modified life cycle cost ($) of the DSM measure: this cost should not include the O & M savings from reduced energy consumption,
D = Annual energy savings (kWh/year), and
LF = Load factor

9.2.4 *Cost of DSM Programme*

In our economical analysis, it will be assumed that the identified DSM options will be implemented through a DSM programme, initiated and implemented, or supervised, by the MEW or electric Utility.

Estimation of running a DSM programme including some or all the identified DSM options is a complex procedure. The cost of the programme varies widely and is somewhat larger than the simple technology costs. The reason is that the costs for running DSM[55] programmes require diverse activities such as publicity, training, equipment, and monitoring, etc.

Most programmes report costs of saved energy of \$0.02/kWh or less (Nadel et al 1990)[56] . In USA, an ACEEE survey of state efficiency found reported lifecycle costs of 2.3 – 4.4 cents per kWh for seven states that reported these costs.

Generally, the programmes with high rates of free-riders (those who consume more than their fair share of a public resource) involve measures that are highly cost-effective and therefore have very low technology costs.

For a vigorous penetration of DSM options, financial incentives like initial capital subsidies, low-interest credit schemes, accelerated depreciation, tax rebates, etc. are essential for successful DSM programmes. Due to the extremely low electricity tariff in Kuwait, we propose that a portion of the initial capital cost, for each DSM option, is to be provided on a cost-sharing basis so that the contribution of utility (MEW) is not less than 50% depending on the DSM measure implemented. In addition to cost sharing, other indirect programme costs are necessary for publicity, generating awareness, information campaign, utility staff salaries, conducting feasibility studies, and costs for evaluating or monitoring programme results.

Total programme cost per kWh saved depends on the measure lifetime and the discount rate used. It also depends on the estimated amount of saved energy on an annual basis (Hirst, 1991)[57], indicates that a utility DSM programme's performance depends on two factors: Participation in the programme and the net savings of the programme. The net savings of the programme is defined as:

Net programme savings = avoided supply costs – total programme costs ………. (5)

The total cost of saved energy consists of two components and can be expressed as follows:

Programme CSE = (Ccap + Cind) . crf / D ……………………… (6)

Where,

CSE = Cost of saved energy (\$ / kWh)
Ccap = Capital cost of end-use technology
Cind = Indirect costs of DSM programme
crf = Capital recovery factor
D = DSM programme annual kWh savings

Calculations of capital cost of end-use DSM measure (Ccap) and the indirect cost of DSM programme (Cind) are based on the following main issues and assumptions:

i) The indirect, or ***fixed,*** programme cost (Cind) consists usually from the initial programme set up cost, programme costs for publicity, generating awareness, conduction feasibility studies, training and monitoring and evaluation of the programme. In our analysis, it will be assumed that the indirect programme cost, for almost all options, is fixed at 2 fils/kWh ($0.006/kWh) of saved energy, i.e. the indirect programme cost for 2010 is approximately 6.3 million KD (≈ $20 million), since the saved energy in this year is estimated at 3139 GWh.

   The assumption of such indirect programme cost is based on the following issues:

   - The cost of the programme per kWh represents only 14% of the minimum avoided energy cost (2/14) and equal to electricity price offered to residential consumers.
   - Programme budget of about $20 million every year is quite reasonable for any DSM pilot programme.

ii) The capital, or direct, cost (Ccap) of the programme depends on the type and complexity of the DSM measure. It is comprised primarily of incremental measure costs. Incremental measure costs are essentially the costs of obtaining energy efficiency. In the case of an add-on device (say, roof insulation, or shading), the incremental cost is simply the installation cost of the measure itself. In the case of equipment that is available in various levels of efficiency (e.g., a central air conditioner), the incremental cost is the excess of the cost of the high efficiency unit over the cost of the base (reference) unit.

   It is important to emphasize that the higher the percentage of measure costs paid by the programme, the higher the participants' benefit-cost ratios and, consequently, the number of measures adoptions.

iii. Rebates, when applied, are structured either as fixed payments per unit (e.g., $10 per electronic ballast) or as payments designed to lower the first cost of a DSM measure to some predetermined level (e.g., to ensure a payback period to the customer within three years).

B/C Model Development:

Calculation of the Benefit/Cost (B/C) ratio for each DSM option is carried out using the following simple formula:

$$B / C \text{ Ratio} = \frac{\text{Benefits (CNPV)}}{\text{Costs (CNPV)}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where,

CNPV is the cumulative net present value

Below, we discuss the main financial parameters of identified DSM options and estimate the levelized costs for each option.

The range of discount rates used in energy efficiency studies vary, with most analysis using a real discount rate of 4-8 percent to evaluate the cost-effectiveness of energy efficiency policy. For example, ACEEE uses 5% while DOE employs a real interest rate of 7%. Over the last few years, most nominal interest rates have been below the real discount rate used by DOE.

In our calculations we assume a real discount rate of 4.5%.

i. Increase of Thermostat Setting (DSM1):

Increase of thermostat set-point from 23^{o}C to 25^{o}C saves, at least, 9% (average simulated savings is 17%). This option costs nothing to implement, i.e. Ccap = 0; the only costs to be spent is the indirect, or fixed, programme costs. We assume that specific indirect programme cost is 2 fils/kWh (≈ $0.006/kWh) of saved energy. Based on simulation results, the total amount of programme cost in the first year of forecast (2010) is approximately KD 2528200 (≈ $ 7.6 million).

ii. High Efficiency Lighting (DSM2):

The majority of Kuwaiti houses use the conventional incandescent light bulbs. Replacement of these bulbs to compact fluorescent lamps (CFL) is an attractive and cost-effective DSM option. The average dwelling in Kuwait consumes roughly from

5000 to 8000 kWh per year on lighting, depending on the type of dwelling. By replacing the existing incandescent lamps with CFL will save, at least, 70% of lighting electricity. The lifetime of CFL is about 10000 hours (≈ 5 years), approximately 10 to 15 times longer than incandescent bulbs. On annualized cost basis, a CFL may cost less than the total cost of all the incandescent bulbs that have been replaced.

In our financial analysis, we focus only on two types of incandescent lamps to be replaced to CFL, the 100 W and the 40 W (frequently used in chandeliers) bulbs. The equivalent CFL lamps are 23 W and 7 W respectively. Table 9.1 shows the basic data of lighting system based on energy audits and market trends.

Table 9.1 Lighting System Basic Data

Incandescent Lamps			**Average Number & Operation**				**CFL**		
Power (W)	Lifetime (Hours)	Cost ($)	Villa	Apart-ment	Tr. House	Avg. Op. Hours/day	Power (W)	Lifetime (Hours)	Cost ($)
100	1000	0.5	28	14	30	6	23	10,000	5
40	1000	0.5	68	16	48	4	7	10,000	5

The average market price of CFL is assumed to be $5 and the percentage of utility sharing is 50%. It is clear from Table 10.1 that, on annualized cost basis, a CFL may cost less than the total cost of all incandescent bulbs that it is replacing.

Table 10.2 shows an example of programme cost components for the DSM lighting option (DSM2). The example is applied to villas participating in the DSM programme starting in 2010 and extended to the end of 2019. From the total resource cost perspective, this DSM option is cost-effective giving a net benefit-to-cost (B/C) ratio of 3. For the consumer, even with 50% cost sharing from the utility, the simple payback period is about 3.4 years, which could be acceptable irrespective of very low electricity price.

iii. High Efficiency Air Conditioning Units (DSM3):

The current stock of air conditioning (A/C) units is inefficient, most of the units has energy efficiency ratio (EER) less than, or equal to 9. As previously analysed by simulation process, we assume that the existing A/C units have been replaced by energy efficient units of EER not less than 11. The incremental cost of efficient units with respect to the existing units is assumed approximately 10 $/RT, therefore, the average budget required to upgrade the existing 45 RT central air conditioning system in a villa, for example, is around $450. The expected life span of the A/C unit is 15 years.

iv. High Quality Wall and Roof Insulation (DSM4)

Different insulating materials are used in Kuwaiti homes for walls and roofs. Insulating the building roofs and walls with high quality 5 cm (2 inches) polystyrene sheets, as well as light coloured surfaces, reduces energy use by, at least, 20% (average simulation savings is 24%). The incremental cost of this measure is about US$500 per dwelling. The life of the measure is estimated at 25 years.

Table 9.2 – Example of DSM Programme Costs for CFL Rebate Programme

Item	Value
A. CFL Rebate Programme – Cost Estimates	
Number of participating Villas (2010)	4290
Number of lamps / villa	28 (100 W) 68 (40 W)
Annual savings /villa (kWh)	5658
Total annual energy savings (MWh) [1]	24273
Total number of lamps adopted through programme (80%)	96096 (100W) 233376 (40W)
Lifetime of CFL (years)	5
CFL market price	$ 5
CFL rebate (%)	50
CFL final price to household / lamp	$2.5
CFL cost to utility / lamp	$2.5
B. DSM Programme:	
B1- Programme Fixed (Indirect) Cost (Publicity, advertising production, campaign, training, etc.) / kWh of saved energy	$0.006 (2 fils/kWh)
Total Programme fixed costs	$145638
B2 – Programme Capital (Variable) Cost	
CFL cost to utility	$823680
Total Utility Cost	$969318
Utility real discount rate	4.5%
Utility capital recovery factor	**0.228**
Equivalent annual utility programme cost	221005
Programme cost of saved energy	$0.009/kWh (≈ 3.0 fils/kWh)
Net savings to Utility [(12- 3) fils/kWh]	9 fils/kWh ($0.027/kWh)
Benefit/Cost Ratio (B/C)	3.0
CFL Cost to Household ($)	2.5 x 96 x 0.8 = 192
Savings from replacing incandescent lamps ($)	76.8
Net Cost of replaced lamps ($)	115.2
Annual energy savings to Household ($) [2]	34
Simple payback period for Household	3.4 years

1. Simulation results indicate higher saving (24273 MWh).
2. Electricity price is 2 fils / kWh ($0.006/kWh)

v. Energy Efficient End-Use Equipment (DSM5)

This option is assumed to be combined with DSM 7, the application of Labels and Standards.

As a starting point for the promotion of Labels and Standards, it is common to start with two or three kinds of end-use equipment, such as refrigerators, washing machines and water heaters. We assume that the incremental cost required to Upgrade these equipment is $150 per unit for villas and traditional houses and $100 per unit for apartments. It will be assumed that 3 units are replaced for each villa and traditional house, and two units for apartment. The lifetime of a refrigerator, washing machine and water heater is assumed to be 10 years.

vi. Tariff Increase (DSM6)

The potential impact of tariff increase depends largely on DSM programme design, tariff policy and information and awareness campaigns. Investment in this option is assumed to be constant at a rate 2 fils ($0.006) per kWh of projected saved energy. For example, the total programme cost allocated to promote tariff increase for villas is 136.42 million US$ (Energy savings (22737 kWh) x $0.006), and the present value of the programme cost on annual basis is 1724000 $/year.

9.2.5 *Cost Effectiveness of DSM Programme*[58]

A number of tests commonly used to assess a DSM programme's cost effectiveness. Most of these tests are based on the perspectives of various stakeholders involved in the DSM process. These tests include the following main types:

- **The Utility Test (UT):**

The UT measures the net costs of DSM as a resource option based on costs incurred by the utility against the avoided costs of the supply.

- **The Participant Test (PT):**

The PT measures the quantifiable benefits and costs to the customer for a given DSM measure. Due to very low electricity price, this test is difficult to be implemented in Kuwait, since the payback period, from the customer perspective, will be very high.

- **<u>Total Resource Cost Test (TRC)</u>[59] :**

The TRC test compares the avoided cost of supply with both the utility and participant costs of a DSM measure. A benefit cost ratio of more than 1.0 indicates that, for the particular group of economic actors, programme benefits outweigh costs, and the programme can be considered cost-effective. In other words, a DSM measure with a total cost of saved energy ($/kWh saved) less than current average electricity avoided supply cost estimated by the Utility (MEW) as 14 fils/kWh ($0.042 / kWh) is considered cost-effective.

The primary test that is used for screening DSM programmes is the *Total Resource Cost Test* (TRC). This test assesses whether or not the programme improves economic efficiency in the broad sense of the term. It compares the benefits of the programmes to society with the costs to society of implementing the programme. The benefits include the avoided cost of capacity and energy while the costs include the equipment and administrative costs involved in executing the programme.

The administrative costs include staff time and other costs that are necessary to design, implement, monitor and evaluate the program impacts. The test excludes any transfer payments between members of the society. Thus, incentive payments by the utility to recruit customers and taxes (of all kinds) that are paid by either the utility or the customer are excluded from the calculation.

The application of these tests for anticipated DSM programme in Kuwait needs careful attention due to the following reasons:

- These tests were developed in the U.S. context to assist the regulator in determining the appropriateness and justification of for various utility DSM programmes and may not be appropriate for other DSM programmes.
- While these tests may be considered as useful indicators for cost-effectiveness, their use may be not sufficient to capture other important benefits, such as building of public awareness, improved customer services, environmental benefits, reduced fuel consumption, and other benefits commonly associated with DSM programmes.

In the analysis the TRC test is used as to evaluate cost-effectiveness. Screening worksheets are used to assess cost-effectiveness for all DSM options.

9.2.6 *Economic Assumptions*

Evaluation of cost-effectiveness and economic parameters are based on the following assumptions:

- US$ is equivalent to 0.300 KD.
- The discount rate = 4.5%
- The life span of end-use equipment considered in the analysis is shown in Table 9.3
- For economic analysis, all values are presented in 2009 with USA dollars, with costs and benefits after 2010 discounted, using the above mentioned discount rate.
- The incremental installed cost of a DSM measure is its cost.
- Net economic benefits are considered over the lifetime of energy efficiency DSM measures installed during 2010-2020.

Table 9.3 Residential Equipment Life Span

Appliance	Average Life Span (years)
Compact Fluorescent Lamps	5
Insulation/Building Envelop Improvement	25
Refrigerators & other end-use equipment	10
Air Conditioning Systems	15
Electric Hot Water Heaters	10-12

9.3 Economic Results

For each type of dwellings, a simple excel spread sheet model was developed for use in calculating Benefit/Cost (B/C) ratio. For each DSM measure, functionality was designed into the spread sheet to quantify benefits by multiplying the annual energy and capacity savings values over their identified measure life, times the cumulative net present value of a nationwide estimate of avoided energy and capacity costs over the same measure life time period.

A summary of these results for all options and for each type of dwellings is shown in Table 9.4. As shown in the table, the net savings for each DSM option, classified by type of dwelling are estimated. The net benefits for all DSM options are approximately:

- US$ 292 million for villas,
- US$ 79 million for apartments,
- US$ 47 million for traditional houses.

The corresponding B/C ratios are 12.5, 9.5 and 8.9 respectively. The total net benefit that could be achieved by implementing all DSM options reaches US$ 417.7 million.

As shown in the Table, all DSM options are cost-effective with B/C ratio higher than 1, except DSM4 (High quality roof and wall insulation) when applied to the apartments, where it gives a negative value. This result for DSM4, under the proposed scenario of investment, makes its inclusion in a DSM programme not warranted.

Table 9.4 Summary of Economic Impact Estimates by DSM Option (2010 – 2019)

DSM Option	ID	Total Savings (1000$)			Total Prog. Costs (1000$)			NET Benefits (1000$)			B/C Ratio [2]		
		Villa	Apartment	TR. House	Villa	Apartment	TR. House	Villa	Apartment	TR. House	Villa	Apartment	TR. House
Thermostat Resetting from 75 to 78 ^{o} F	DSM1	133275	54376	27669	715	214	138	132561	54163	27532	185.4	253.7	200.0
Replacing Incandescent Bulbs to CFL	DSM2	139138	50057	32367	943	3012	1545	138195	47045	30822	146.5	15.6	20.0
Upgrade A/C Equipment to Efficient Units with EER ≥ 11	DSM3	92413	31799	15928	2635	1083	688	89778	30716	15240	34.1	28.4	22.2
High Quality Wall and Roof Insulation	DSM4	48833	26	682	980	159	177	47853	-133	505	48.8	-0.8	2.9
Use Energy Efficient End-Use Equipment [1]	DSM5	15523	2573	1358	2399	1676	722	13124	896	636	5.5	0.5	0.9
Tariff Increase	DSM6	158387	52902	32350	17183	5402	3362	141204	47500	28988	8.2	8.8	8.6
Total		**315156**	**87299**	**52298**	**23393**	**8354**	**5267**	**291763**	**78945**	**47031**	**12.5**	**9.5**	**8.9**

(1) Combined with DSM7 (Labels and Standards)
(2) Cost-effective if B/C > 1.0

9.4 Environmental Impacts

Electricity generation results in the emission of pollutants, i.e. CO_2, SO_2, NO_2 and fly ash. We shall focus on the emission of CO_2, the main contributor in Greenhouse Gas (GHG) emissions. Estimation of reduction in GHG emissions is becoming increasingly important as climate change becomes a driver for many sustainable – energy projects, including energy efficiency DSM projects.

The amount of GHG emissions decreased, or avoided, will depend on the DSM energy efficiency measure used and the generation mix as well as type of fuel used in power generating systems before and after the energy efficiency programme. In Kuwait, power plants use both natural gas (NG) and liquid fuel. Specific data on fuel consumption rates (gm/kWh) and power plants environmental aspects are not available. However, the total type fuel and amount of energy used (in billion Btu) in each of the power plants are available (see Table 9.5). Part of this energy is used for desalination, thus the actual plant efficiency actually higher than that shown in Table 9.5. Based on our estimates, the average specific energy consumption, for the five plants is approximately 10556 Btu/kWh, (1Btu = 1055.1J = 0.2931Wh), and the average thermal efficiency is 32.6%. It is clear from the table that the amount of natural gas consumption represents 24% of total thermal energy used in generation and the rest is fired by fuel oil. The amount of energy used in all power plants (in billion Btu) is shown in Figure 9.1 classified by type of fuel.

Table 9.6 shows the approximate rates of carbon emissions for natural gas and fuel oil (US EPA, www.epa.gov). In our calculations we use the emission factors given in Table 9.6, to estimate the amount of CO_2 reduction, taking into consideration the percentage sharing between natural gas and fuel oil.

Table 9.7 shows the saved energy during the period of forecast and the results of calculations for reduced CO_2 emissions. The average amount of CO_2 reductions per year is approximately 2.68 million tonne, and the aggregate sum of these reductions may reach 26.8 million tonne by the end of 2019.

Currently, under Certified Emission Reduction (CER), the average price of CO_2 in the carbon market ranges approximately from 10 to 12 € (≈ US$ 13-16) per tonne, thus, the annual income from the saved CO_2 might reach 38.9 million US$ (≈ 13 million KD), and the total income that could be achieved by CO_2 mitigation is estimated at approximately US$ (26.8 million tonne x 14.5 $/tonne). This income could be promoted through Clean Development Mechanism (CDM).

By combining the technological, policy and environmental DSM opportunities, we conclude that the overall revenues that could be achieved by implementing the identified DSM options may reach US$ 843 million, at the end of forecast period.

Table 9.5 Power Plants Energy Consumption in Billion Btu Classified by Fuel Type (2006)

Power Plant	Natural Gas (b. Btu)	Gas Oil (b. Btu)	Crude Oil (b. Btu)	Heavy Oil (b. Btu)	Total (b. Btu)	Generated Energy (GWh)	Consumption Rate (Btu/kWh)	Average Efficiency (*) (%)
Shuwaikh	8433	0	0	0	8433	0	**--**	--
Shuaiba	41874	0	0	0	41874	4058	**10319**	**33.1%**
Doha East	17338	159	31215	14565	63277	5128	**12340**	**27.7%**
Doha West	15416	0	0	110915	126331	12066	**10470**	**32.6%**
Az-Zour South	39540	23318	0	114150	177008	16173	**10945**	**31.2%**
Sabia	5682	45	25631	58342	89700	10180	**8811**	**38.7%**
Total	**119850**	**23522**	**56846**	**297972**	**498190**	**47605**	**10465**	**32.6%**
%	**24.1%**	**4.7%**	**11.4%**	**59.8%**	**100.0%**		**10558**	**32.6%**

Source: MEW Statistical Year Book 2007

(*) Estimated

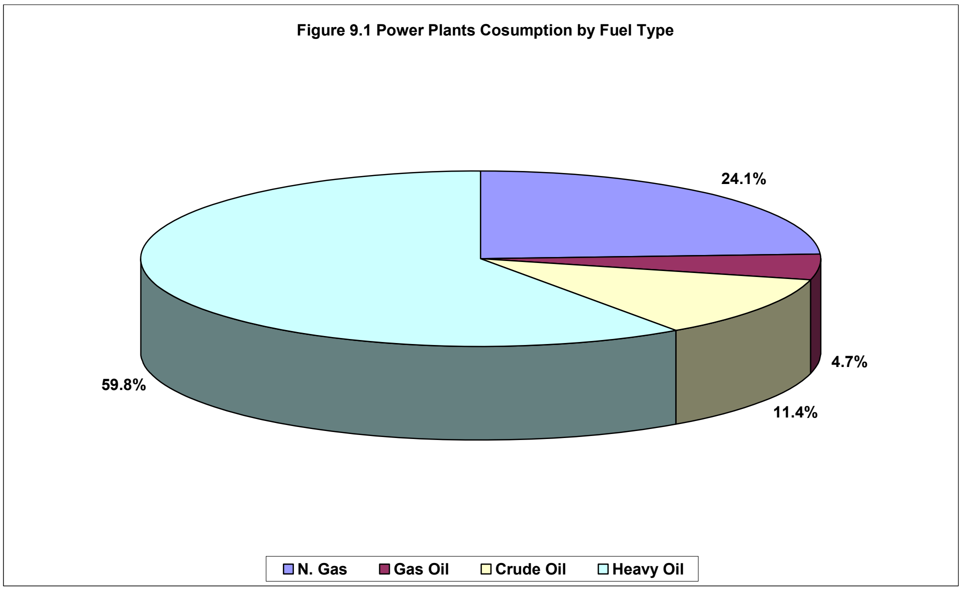


Table 9.6 CO2 Emissions from Fuels Used in Kuwait Power Plants

Fuel	CO_2 Emitted (lbs/million Btu)	CO_2 Emitted (kg/GJ)
Natural Gas	117.1	49.9
Fuel Oil	161.4	68.8

Source: US EPA web site www.epa.gov/appdstar/pdf/brochure/pdf

Table 9.7 - Annual Reductions of CO_2 Emissions

Year	Saved Electrical Energy (GWh)	Saved Thermal Energy (billion Btu)	CO_2 Reduction (1000 lb)	CO_2 Reduction (1000 tonne)
2010	3139	33141.6	4982005.3	2259.82
2011	3482	36763.0	5526391.4	2506.75
2012	3518	37143.0	5583528.1	2532.67
2013	3571	37702.6	5667646.1	2570.83
2014	3633	38357.2	5766048.2	2615.46
2015	3718	39254.6	5900954.4	2676.66
2016	3833	40468.8	6083474.5	2759.45
2017	3962	41830.8	6288214.4	2852.32
2018	4111	43403.9	6524697.0	2959.58
2019	4263	45008.8	6765940.9	3069.01
Avg.	**3723.0**	**39307.4**	**5908890.0**	**2680.3**
Total	**37230.0**	**393074.3**	**59088900.2**	**26802.5**

9.5 Summary

In this Chapter, the identified DSM options are analysed regarding their economical and environmental impacts. The analysis has arrived to several conclusions, including:

First, the required investment rates, for the identified DSM options, are relatively modest, ranging from 100,000 to 2,500,000 US$ annual investment by the end of 2019.

Second, from the total resource cost perspective, most of the DSM options are strongly cost-effective. Table 9.8 shows the economic parameters for all types of dwellings classified by DSM option. The most cost-effective option is the increase of thermostat set-point (DSM1), and the least cost-effective is the use of efficient end-use equipment (DSM5).

Third, DSM4, The use of high quality roof and wall insulation, is not cost-effective (in case of apartments, giving a negative B/C ratio. This option may need more contribution from the customer and/or less cost sharing from the Utility (MEW).

Fourth, DSM options, through a dedicated programme, can have a significant impact on GHG emissions, at relatively modest costs. By the year 2020, the sum of potential CO2 reductions may reach 26.8 million tonne. The cost of achieving these savings is approximately US$351 million.

Finally, significant policy changes will be needed to achieve these impacts, including gradual tariff adjustment, more involvement by Utility, or government, and the creation of sustainable DSM programmes.

Table 9.8 – Economic Parameters of DSM Options (2010 – 2019)
(Dollars in $1000, Present Value)

DSM Option	ID	Programme Costs	Resource Savings	Net Benefits	B/C Ratio
Thermostat Resetting from 75 to 78 ^{o} F	DSM1	1067	215321	214254	**200**
Replacing Incandescent Bulbs to CFL	DSM2	5500	212552	207052	**37.7**
Upgrade A/C Equipment to Efficient Units with EER ≥ 11	DSM3	4406	140140	135734	**30.8**
High Quality Wall and Roof Insulation	DSM4	1316	49540	48224	**36.6**
Use Energy Efficient End-Use Equipment	DSM5	6113	19454	13432	**2.2**
Tariff Increase	DSM6	25947	243640	217643	**8.4**
Total		**44349**	**454753**	**410404**	**9.3**

The average amount of CO_2 reductions per year is approximately 2.68 million tonne, and the aggregate sum of these reductions may reach 26.8 million tonne by the end of 2019. This mitigation of CO_2 could achieve an annual income of approximately US$ 38.9 millions.

Chapter 10

Conclusions and Recommendations

10.1 Conclusions

Kuwait is among the fastest growing countries in the Gulf, and the electricity demand is growing even faster than the country's population. Kuwait has one of the largest per capita consumption in the world, reaching 13061kWh in 2006 (MEW, 2007). The power sector in Kuwait is not commercially viable, due to the current under-pricing policy and heavily subsidized tariff.

The core objective of this thesis is to answer the following question: What are the potential impacts of identified DSM measures on peak demand and energy consumption of the residential sector, and what are the economic and environmental benefits of these impacts?

To answer this question, a practical and a theoretical framework were developed. The practical framework includes detailed energy audits and measurements for selected typical models of residential dwellings (villas, apartments and traditional houses). The theoretical framework includes simulation process for audited dwellings, the use of Analytic Hierarchy Process to prioritize DSM options and conducting financial spread sheet analysis to estimate the economic and environmental benefits. Moreover, the methodology included the development of baseline scenario and demand forecast for the period 2010 to 2019 (inclusive).

The residential sector in Kuwait consumes about 65% of total electricity consumption, and is characterized with inefficient use of energy due to several factors, including very cheap energy price and lack of awareness.

The major findings of this research study are:

- The research showed that a DSM portfolio consisting of seven identified measures, and through a dedicated programme, could have substantial reductions in energy consumption and peak demand as follows:
- DSM1: Increasing thermostat setting by 3 degrees (from 75 ^{0}F to 78 ^{0}F), is the most cost-effective option for the utility and at no cost for the consumers. This option could achieve accumulated energy savings of about 1278 GWh across the

period of forecast and the average peak demand reduction per year was estimated at 156 MW. The total net accumulated savings is approximately US$ 214 million, and the benefit/cost of the programme is about 200.

- DSM2: Replacement of about 80% of the widely used incandescent lamps of rated power 40 W and 100 W to CFL of rated power 7W and 25W respectively, could achieve savings in energy up to 1351 GWh, and reductions in peak demand 184 MW in average for all types of dwellings. Even with 50% cost sharing with the customer, the utility could achieve a B/C ratio of about 38.
- DSM3: Upgrading existing A/C systems to more efficient types with EER ≥ 11, instead of 8.5 – 9.5 currently used. The potential energy savings may reach 574 GWh during the forecast period, and the average peak demand reduction is 95 MW per year. The estimated B/C ratio of this option is approximately 31.
- DSM4: The use of light coloured roofs and walls with high insulation material. The results of analysis indicated that this option could achieve a total energy savings of 79 GWh, and total benefits of about $48 million, with B/C ratio 37.
- DSM5 (Combined with DSM7): The use of energy efficient end-use equipment, the application of labels and standards. The results of research indicated that this option is the least cost-effective with B/C ratio 2.2 and the achieved energy savings across the 10 years period of forecast is approximately 157 GWh and the average reduction in peak demand per year is 8 MW.
- DSM6: Tariff increase; gives in the average 3110 GWh of saved energy and 226 MW of peak demand reduction per year, assuming the cost of DSM programme estimated at US¢ 0.6 per kWh of saved energy and the price elasticity is -0.1. The overall B/C ratio was estimated at 8.4.

The potential overall energy savings and peak demand reductions that could be achieved with simultaneous implementations of all seven DSM options are shown in table 10.1 in Appendix 10.

The research showed that the total accumulated energy savings across the forecast period was estimated at approximately 34549 GWh, and the total peak demand reductions during at the end of forecast (2019) reaches 1530 MW representing 8.9% of the overall peak load.

With respect to the type of dwelling, the research also indicated that the total net revenues for the utility were estimated at: $292 million for villas, $79 million for apartments and $47 million for traditional houses.

One of the important indicators showed as a result of implementing the identified DSM measures is the positive environmental impact that could be achieved by reducing CO_2 total emissions by approximately 26.8 million tonne across the forecast period (2010-2019), which could achieve an annual income of about US$38.9 million.

The thesis recognized the barriers and difficulties which could be met for the implementation of identified DSM measures, and stressed the importance of continuous adaptation and institutional learning in the implementation process.

Integrated DSM policy recommendations were formulated, including gradual tariff adjustment, and more involvement by the utility, or government, in the creation of sustainable DSM programmes.

10.2 Barriers to DSM Implementation

One of the fundamental steps necessary to enable successful implementation of any strategy, including DSM, is the need to understand the barriers confronting it, and how to overcome them.

Experience in DSM by many countries, had shown the existence of some barriers facing its implementation; namely: energy pricing, the bias towards supply options coupled with lack of awareness, institutional, technical, financial and administrative problems. Several of the more traditional barriers are self-evident, and are described briefly below.

- **Energy Pricing:**

Low electricity price is likely to be a key barrier to uptake DSM implementation in most of the developing countries, particularly in Kuwait, where consumers have historically faced low unit price of electricity. Although significant progress has been made in reducing energy subsidies in developing countries, subsidies in Kuwait still remain as high as 5 times the current energy price.

- **Bias Towards Supply Options:**

The traditional planning mind set tends to associate greater credibility with highly centralized power plants and does not favour investments in DSM and energy conservation measures or decentralized options of electricity production. There should be some incentives for electric utility to invest in DSM / EE in order not to be "supply focussed".

- **Lack of Awareness:**

Consumers are frequently unaware of practices and technologies available for energy conservation. They may be operating their electrical equipment incorrectly or wastefully. For example, residential consumers might place their air conditioning in direct sunlight, which is very severe in Kuwait, and this will increase its electricity consumption.

In many cases, customers do not understand the range and benefits of air conditioning system efficiency. Contractors tend not to be trained effectively in key elements of proper installation or duct sealing, and have little incentives to become more knowledgeable and aware of energy efficiency.

An important role of any DSM strategy is to increase awareness in such matters and to bring knowledge and understanding into the various sectors. This will be achieved through awareness campaigns, demonstration programmes, audits and education, and public building sector energy efficiency implementation initiatives. Use of the mass media and electronic options such as websites will be fully explored to publicise energy-saving tips, energy management tools and best practice methods.

- **Institutional and Legal Barriers:**

DSM programmes and plans for energy efficiency strategies are complex and need an appropriate institutional setting in order to be conceived and implemented. Frequently, planning agencies suffer from the lack of personnel with good knowledge of the behaviour of the energy market and how to implement policies to alter existing trends of energy consumption and their evolution. At the same time the personnel need to understand the several existing options on the supply side as well. Decisions have to be taken concerning capital investments, and operating costs of a number of alternatives. These alternatives, usually, take into account several projections of future prices, load growth, and interest rates. These tasks require technical skills and tools so that the potential for DSM measures are properly evaluated and the instruments to implement them conceived.

Legal barriers frequently limit the scope of the planning activities of the electric utilities (in Kuwait, the concerned departments in the MEW). For example, the electric utilities in most of the developing countries are usually legally defined as being responsible for supplying electricity only, and are required to make investments only in the power sector.

Legal accounting procedures impede electric utilities from considering investments in their consumer' facilities as part of the utility investment, and therefore such investments cannot be taken into consideration when rates are calculated, for example.

- **Technical Barriers:**

In many cases, the DSM energy efficiency opportunities depend on new technologies which might not be available in some countries or regions. Product availability is important in order to create a sustainable market for the technologies being introduced. Most of the end-use equipment in Kuwait are imported, but ongoing technical support needs to be available locally; other wise lack of maintenance and support will also constitute a barrier for success in implementing the DSM options.

The quality of equipment being locally produced (or imported) is also important to guarantee the good performance of the electrical system as a whole. For example, the selection of electronic ballasts for fluorescent lamps, should not only save energy, but also must satisfy minimum requirements for the level of harmonics and power factor.

The technical infrastructure in Kuwait, in particular the lack of individual control of air conditioning and lighting, prevents fast and simple energy conservation measures like turning off unused devices. Changes in infrastructure will require some lead-time.

- **Lack of Information:**

Consumers often lack information regarding the costs and benefits of technologies or services that deliver higher energy efficiency. Even when information is provided by technology suppliers, consumers face difficulties in evaluating the applicability of claims made for particular product or service.

The lack of substantial data bases restricted the scope of the research that could be completed in a reasonable length of time. Data bases are needed both for energy consumption in Kuwaiti buildings and for housing stock classified by type of building.

Other barriers exist for individual air conditioning related measures such as the perceived aesthetics of light-coloured or reflective roofs, and lack of knowledge of the cost effectiveness of insulation or radiant barriers.

Lack of knowledge and interest among builders regarding efficient building techniques.

Lack of knowledge among customers and contractors that many A/C systems are not correctly sized or installed and that this have impacts on energy cost and comfort.

10.3 Funding and Incentives

- Funding is an important factor in the diffusion of DSM programme. MEW can fund some programmes and from whom significant demand reduction takes place; the money can be recovered in installations along with monthly bills.
- Some countries have introduced incentives for buildings that perform better than regulatory standards. Incentives could be offered in the form of subsidies for investments in energy efficiency based on projected annual energy saving. Tax credits are another form of incentives used for the same purpose. Analysis of such approaches suggests that subsidies at the design and construction stage have substantially greater impact on building performance than incentives based on operating costs, such as energy taxes.

10.4 Recommendations

The conclusion of the present work indicates the urgent need, for the residential sector in Kuwait, to direct efforts toward upgrading residential energy efficiency and take the steps for the implementation of a pilot DSM programme for the sector. In view of such needs and in line with the need for developing a more sustainable energy sector as well as sustainable buildings, the following may be recommended:

The government of Kuwait should give serious consideration to the adverse effects of the current energy consumption trends, particularly in the residential sector, on both the economy and the environment. The country should move towards more sustainable energy patterns through the implementation of appropriate policy, regulatory and technological DSM measures.

- It is highly important to create a DSM unit within MEW or MOP to plan and manage all further DSM activities to ensure a co-ordinated approach. As DSM has a strong planning component, MOP would provide the appropriate institutional background for such a DSM unit.
- The first and most important task, for the DSM unit would be the establishment of a reliable statistical database and the commissioning of the research studies and surveys required to provide the basis for a successful DSM strategy. This will include the improvement of consumer statistics in MEW, as well as the completion of research results already available by KISR.
- Establishing a reliable database and data analysis are the pre-requisites for the development of a DSM strategy. DSM measures should only be introduced when their impact can be predicted with sufficient accuracy.
- A least cost planning approach can ensure that energy efficiency and DSM have a level playing field with supply options. The MEW should adopt this approach while approving new capacity additions. This could include Bidding for DSM.
- In assessing potentials and developing energy efficiency DSM projects for residential sector, the following has to be considered:
    a. Special attention has to be given to the no cost/low cost energy conservation measures such as housekeeping (e.g. thermostat re-setting and switching off un-used equipment). Low cost measures distributed to many end-users can result in a large savings normally difficult to achieve without large capital investment, provided the project is managed effectively.
    b. Detailed energy audits are required, especially for private houses of high consumption (more than 9000 kWh/month), which may come up with cost-effective DSM projects.
    c. Priority is to be given for adopting simple, locally handled and sustained technologies rather than high-level sophisticated systems with a short-term sustaining period.

- Demonstration projects are important tools and successful ways of convincing rate-payers of the effectiveness of energy efficiency DSM measures. Demonstrations should focus on technologies and end-uses that are relevant to the rate-payers. For residential sector, technologies to be considered should include energy-efficient cooling systems, lighting, and energy-efficient appliances.
- The high transaction costs of DSM programme by the utility (MEW) could be a barrier. However, any DSM programme should have a positive effect on the utility and have significant saving potential. The challenge, also, is to generate consumer participation / interest since they pay highly subsidised tariff.
- The government should form joint working groups of representatives of the Ministry of Electricity and Water (the sole provider of electricity) and representatives of the Public Authority of Housing Welfare (a major provider of the buildings housing), with a view to verifying the application of regulations and regulations to improve residential building standards (selection of building materials, improvement of energy efficiency and efficient buildings, etc.).

- Innovative Programme Design:

Focused DSM programmes that target the barriers involved and have low transaction cost need to be designed. A large number of pilot programmes need to be tried with different institutions, incentives, and implementation strategies. KISR can play an important role in these programmes. A few suggestions are included here:

10.4.1 *Efficient Lighting Initiative*

The use of energy efficient lamps has a large potential of savings in Kuwait, since most of the residential consumers use conventional incandescent lamps. Electric utility of Kuwait (MEW) should launch pilot efficient lighting initiatives in towns / cities. Features should include warranties by manufactures or suppliers, incentives and / or deferred payment through utility bill savings

One of the best and successful DSM programmes in high efficiency lighting was implemented in Thailand during 1993 to 2000. The programme was the primary reason for the manufacturers to shift production from the normal fluorescent lamps to the energy-efficient "thin tube" (T-8) lamps[60].

Thailand probably has the most extensive experience in programme evaluation, having completed a detailed evaluation costing US$4 million and engaging multiple consultants to assist in the DSM effort. Thailand's experience has underlined the importance of a concurrent evaluation process being an integral part of DSM[61].

International examples in efficient lighting are also available at: www.efficientlighting.net.

10.4.2 Green Building Initiative[62]

Although the concept of green building (GB) is relatively new, today, it is one of the fastest growing building and design concepts. Green building is a "whole-system" approach for designing and constructing buildings that conserve energy, water, and material resources and are healthier, safer and more comfortable.
In practical terms, green buildings are designed and constructed to:

- Incorporate energy efficiency features (use natural ventilation and lighting, good insulation, high efficiency lighting, green roofs, solar or geothermal energy).
- Incorporate water efficient features (e.g. use waterless urinals, low-flow faucets and toilets, etc.).
- Re-use existing building structures and/or building materials; reduce and recycle waste materials.
- Preserve natural vegetation, and reduce disturbance to landscape and habitats, in order to maintain bio-diversity and preserve ecological integrity.
- Incorporate sustainable, healthy, locally made or harvested non-toxic materials and features into buildings (e.g. FSC or recycled wood, low VOC carpets, paint and composite wood products, previously used or recycled materials).
- Incorporate flexible design and durability whenever possible (e.g. movable walls that don't require renovation to reconfigure).

And for operation and management, green buildings:

- Use green waste management practices.
- Use non-toxic cleaning products.
- Monitor and commission building installations and building operations to ensure that planned targeted designs are met with results.

Recent research confirms that it makes good economic sense for governments to support green buildings design and practice. In the United States, a 2003 report to the California Sustainable Building Task Force predicted:

> *While the environmental and human health benefits of green buildings have been widely recognized, minimal increases in up-front costs of 0 to 2 percent to support green building design will result in life cycle savings of 20 percent of total construction costs – more than 10 times the initial investment*[63].

Several green building rating systems are now in use to evaluate and certify green buildings. Examples of these rating systems are: LEED (Leadership in Energy and Environmental Design), developed by the US Green Building Council (USGBC) as a national standard for high performance sustainable buildings, BREEAM (BRE Environmental Assessment Method), created in UK, in 1990 with the first two versions covering offices and homes, and LEED India, established and administered by the Indian Green Building Council (IGBC) under licence agreement with the USGBC.

10.5 Future Research Work

The following research topics are highly attractive and important for Kuwait:

1. Integrating Demand Side Management Programmes into Resource Plan of Kuwait

DSM has become more integral to utility strategic plans, and experience with DSM field implementation has grown substantially over the past few years. During this time, most utilities have emphasized programme selection, design, and implementation.

In Kuwait, the integration of DSM into resource planning is important to be investigated and studied in depth.

Equally important is obtaining the assurance that DSM programmes are effectively designed and efficiently implemented and that they provide valued services to customers.

The research addresses and investigates the main Integrated Resource Planning (IRP) options, including, but not limited to, the following action:

- Integrating DSM programmes with supply expansion. The key element of the IRP process is to bring the economic evaluation of energy efficiency into an equal basis with supply expansion.
- The opportunity of integrating private producers and cogeneration with Utility generation. In Kuwait, as most of the developing countries, the high rate of growth in the demand for electric service will still require expansion of the central generating capacity. However, the potential of introducing small-scale generating units, such as industrial stand-by generators and cogeneration could be cost-effective. A further goal of resource planning is thus to allow the evaluation of such sources on an equal basis with central supply expansion.
- Integrating public total resource perspective with the utility perspective.
- Integrating environmental impacts and risks with cost analysis. Environmental issues are likely to be more important in the future as concerns over the regional and global environment, including the potential threat of global climate change, become increasingly serious. The costs of environmental emissions from electricity supply are put of the costs avoided through selection of DSM and renewable supply sources. These costs can be quantified either as emission charges actually paid by the utility, or they can be proxy values used to prioritize and select DSM and supply options in the IRP process.

2. The challenge for the development and diffusion of renewable energy technologies: Solar Power in Kuwait

By burning fossil fuels, electrical power generation affects not only the environment directly and the global climate potentially but the nation's economic strength and its prospects for energy security as well. Using solar power, wind power, and other forms of renewable energy to generate electricity is one response to these concerns.

The research is aiming to investigate the potential of utilization of solar power in Kuwait, particularly in all sectors of Kuwait.

Kuwait, as all countries in the Middle East, enjoys excellent solar resources with an annual average of global solar radiation approximately 6.2 kilowatt hour per square meter (kWh/m2) per day (UN ESCWA Report, NY, 2001). The annual average of total cloud covers can be as low as less than 10%.

With the trend of high electricity demand in Kuwait, and under the conditions of environmental concerns, there is a need for the development and dissemination of renewable energy, particularly solar power.

The study has to assess the institutional framework for solar power development, and areas of potential applications. Assessment of national capabilities in the field of education, training, information and certification is also important to be investigated.

It is important in the research, to include the optimization of solar cooling systems for buildings, solar thermal power desalination systems, and solar water heating systems. Moreover, the opportunity of manufacturing low-cost solar water heaters for residential use, from locally available material, is also important.

REFERENCES

[1]Solar Energy Research Institute. DSM pocket guidebook, Volume 1: Residential Technologies (SERI/TP-254-4098A. CO (USA): Solar Energy Research Institute; 1991.

[2]Solar Energy Research Institute. DSM pocket guidebook, Volume 1: Commercial Technologies (SERI/TP-254-4098B. CO (USA): Solar Energy Research Institute; 1991.

[3]Solar Energy Research Institute. DSM pocket guidebook, Volume 2: Industrial Technologies (SERI/TP-254-4098C. CO (USA): Solar Energy Research Institute; 1991.

[4]The Energy Information Administration (EIA), Demand Side Management Programme, annual report, 1999, Stockholm: International Energy Agency, 2000.

[5]Joskow P., Marron D. "What does a Negawatt really cost" Evidence from utility conservation programs. Energy J., 1993.

[6]Ali E. H. Hajiah "Energy Conservation Program in Kuwait": A Local Perspective, Department of Building and Energy Technologies, KISR 2007, Kuwait.

[7]Al-Marafie, A.M.R. R.K. Suri and G.P. Maheshwari, 1989. Energy and Power Management in Air-conditioned buildings in Kuwait. Energy 9 557-562.

[8]R.K. Suri, G.P. Maheshwari, and M. Sebzali, 1984. " Cool Storage Assisted Air-conditioning Systems". Department of Building and Energy Technologies, KISR, Kuwait.

[9]Essam Al-Sayed O. Assem " Kuwaiti Code for Energy Conservation in Buildings". Department of Building and Energy Technologies, KISR 2003, Kuwait.

[10]D. Al-Nakib "Energy Conservation Opportunities for Lighting Systems in Office Buildings". Department of Building and Energy Technologies, KISR 2002 , Kuwait.

[11]The Ministry of Energy (Electricity & Water), State of Kuwait, Statistical Year Book, 2007.

[12]International Energy Agency (IEA), Key World Energy Statistics-2006, "Selected Energy Indicators for 2004".

[13]IEA, World Energy Outlook 2005, Middle East and North Africa Insight (Chapter 6), 2007.

[14]Energy Information Administration (1995). U.S. Electric Utility Demand Side Management 1994. Washington DC, EIA.

[15]Electric Power Research Institute. Demand –Side Management, 5 volumes. AE/EM-3597. Palo Alto 2002, CA, USA.

[16]The International Institute for Energy Conservation- ECO II, DSM Best Practices Guide Book, 2005.

[17]Gellings, C.W. and J.H. Chaberlin (1993), Demand Side Management: Concepts and Methods. Liburn, GA, USA, the Fairmont Press, Inc.

[18]United Nations Environmental Programme (1992). Agenda 21. New York, United Nations.

[19]S. Boyle, DSM Progress and Lessons in the Global Context. International Institute for Energy Conservation – Europe, London, UK, 1996.

[20]National Resource Defence Council, Demand-Side Management in China"- Appendix IV, International Experience with Demand-Side Management, October, 2003.

[21]Sioshansi, F. P. (1995). "Demand-Side Management: The Third Wave. "Energy Policy 23(2): 111-114.

[22]National Resources Defence Council (NRDC), Demand-Side Management in China, Appendix IV, "International Experience with DSM", October, 2003.

[23]UNEP. Tools and Methods for Integrated Resource Planning. November, 1997.

[24]"DSM in Thailand : A Case Study" . UNDP, World Bank, Energy Sector Management Assistance Programme (ESMAP), October, 2000.

[25]J. Singh and C. Mulholland. DSM in Thailand: A Case Study, October, 2000.

[26]Energy Conservation and Environment Protection. USAID Project (1989-1998), Cairo, Egypt.

[27]Proceedings of the: "DSM and the Reforming Energy Market Conference", December, Cairo, Egypt, 1997.

[28]Ministry of Planning, State of Kuwait "Future Expansion in Generation and Transmission for the State of Kuwait", Final Report, January 2000.

[29]Ministry Of Planning, Census and Statistical Sector, www.Kuwait-info.com.

[30]Statistical Abstracts in 25 Years. Special Issue 1990 and Annual Statistical Abstracts, 1998.

[31]Al-Qabas Newspaper, Kuwait, 12 August, 1999.

[32]Golden, B., Wasil, E. and Harker, P. (eds.) 1989. The Analytic Hierarchy Process: Applications and Studies, Springer Verlag, New York.

[33]Ahmed A. Al-Mulla, PhD., Energy Building Technologies Department, KISR, Kuwait. (An expert, personal contact)

[34]A.R. Khozam, PhD., Energy Expert, Consultant, Energy Efficiency Improvement and GHG Project (GEF/UNDP), Cairo, Egypt (Director of a Pilot DSM Programme in industrial sector from 1994 to 1998).(An expert, personal contact)

[35]I. Yassien, PhD., Ministry Of Electricity and Energy, Director of EEIGGR Project (GEF/UNDP), Cairo, Egypt. (The project supervised and implemented several DSM projects).(An expert, personal contact)

[36]Stephen Wiel, J.E. McMahon, " Energy – Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting", 2nd Edition, 2005.

[37]Lahmeyer International GmbH – The Associated Engineering Partnership , LI/GE 7 / 260046, January 2000.

[38]Saaty TL, The Analytic Hierarchy Process, New York, McGraw-Hill, 1980.

[39]Saaty TL How to Make a Decision: The Analytic Hierarchy Process, European Journal of Operational Research, North Holland, 1990, -48: 9-26.

[40]Expert Choice, Inc., "Expert Choice Software and Manual". 4922, Elsworth Ave., Pittsburgh, PA, 15213, USA.

[41]www.expertchoice .com, Expert Choice, Inc. (5).

[42]Forman, EE. And Selly, M. 2001. Decision by Objectives. Expert Choice, Inc. USA.

[43]The Economic Impact of Changing the Structure of Electricity Pricing in Kuwait. Final Report, 1987.

[44]Suozzo, M. and Nadel, S. 1996. What Have We Learned from Early Market Transformation Efforts?, ACEEE, August.

[45]Packcy, Daniel, J. 1993, "Market Penetration of New Energy Technologies". U.S. Dept. of Energy, National Renewable Energy Laboratory.

[46]Rogers, E.M. The Diffusion of Innovations, 5th Edition, 2003

[47]Dmitry Kucharavy, Roland De Guio, “Logistic Substitution Model and Technological Forecasting", LGECO, France 2005.

[48]"Best Practices in Technology Deployment Policies", Hans Nilsson 2001.

[49]KISR, The Economic Impact of Changing the Structure of Electricity Pricing in Kuwait. Final Report, June 1987.

[50]G. Papagiannis, A. Dagoumas, N. Lettas, P. Dokopoulos, 2008. Economic and environmental impacts from the implementation of an intelligent demand side management system at the European level. Energy Policy, Volume 36, Issue 1, Pages 163-180

[51]UNEP, Joel N. Swisher, at al., "Tools and Methods for Integrated Resource Planning". November 1997.

[52]The Tellus Institute, “Best Practice Guide: Integrated Resource Planning For Electricity”, Prepared for: Energy and Environment Training Program, Office of Energy, Environment and Technology Global Bureau, USAID Office of Energy.

[53]J.N. Sheen “Economic Profitability Analysis of Demand Side Management Program”, Dept of Electrical Engineering, Taiwan, 2005.

[54]C. P. Maheshwari, R. Al-Murad, “Impact of Energy Conservation Measures on Cooling Load and Air-conditioning Plant Capacity”, Building and Energy Technologies Dept., KISR, Kuwait, 2000.

[55]Martin Kushler, Dan York and Patti Witte, Five Years In: An Examination of the First Half-Decade of Public Benefits Energy Efficiency Policies, ACEEE, April 2004, p.30.

[56]Nadel, S., Wolcott, D., Smith, P., Flaim. T., 1990. “A Review of Utility Experience with Conservation and Load Management Programs for Commercial and Industrial Customers”.

[57]Hirst, E., J. Reed, 1991. “Handbook of Evaluation of Utility DSM Programs,” ORNL/CON-336, Oak Ridge National Laboratory.

[58]“Public Service New Mexico Electric Energy Efficiency Potential Study”/ Methodology.

[59]W.W. Clark II, A Sowell, et al, “The Standard Practices Manual: The Economic Analysis of Demand Side Programs and Projects in California”, USA, 2002.

[60]”DSM in Thailand: A Case Study”, UNDP, World Bank, Energy Sector Management Assistance Program, Oct. 2000.

[61]”DSM in the Electricity Sector: Urgent Need for Regulatory Action and Utility-Driven Programmes”. Report by: Prayas Energy Group (Pune), February, 2005.

[62]S. Rutherford, "The Green Buildings Guide", West Coast Environmental Law.

[63]LEED India / Terri Griha (http: // www.teriin.org).

APPENDICES

Appendix to Ch 4

Design Parameters:

City Name	**Kuwait City**	
Location	**Kuwait**	
Latitude	**29.2**	Deg.
Longitude	**-48.0**	Deg.
Elevation	**180.0**	ft
Summer Design Dry-Bulb	**117.0**	°F
Summer Coincident Wet-Bulb	**69.0**	°F
Summer Daily Range	**27.7**	°F
Winter Design Dry-Bulb	**38.0**	°F
Winter Design Wet-Bulb	**31.9**	°F
Atmospheric Clearness Number	**1.00**	
Average Ground Reflectance	**0.20**	
Soil Conductivity	**0.800** BTU/(hr-ft-°F)	
Local Time Zone (GMT +/- N hours)	**-3.0**	hours
Consider Daylight Savings Time	**No**	
Simulation Weather Data	**Kuwait City (Avg)**	
Current Data is	**2001 ASHRAE Handbook**	
Design Cooling Months	**January to December**	

Design Day Maximum Solar Heat Gains

(The MSHG values are expressed in BTU/ hr-ft²)

Month	N	NNE	NE	ENE	E	ESE	SE	SSE	S
January	24.6	24.6	33.1	112.3	185.7	228.4	253.4	248.6	238.9
February	28.2	28.2	74.6	148.5	213.6	245.1	246.1	225.7	209.8
March	32.1	34.5	120.2	185.2	224.8	241.3	220.7	184.4	161.5
April	36.0	79.5	153.8	205.4	225.9	214.6	181.5	129.4	100.0
May	39.6	110.8	173.5	212.4	219.6	193.7	148.2	87.8	61.8
June	51.4	120.0	180.3	212.8	213.5	182.4	133.1	72.1	51.2
July	41.1	110.1	172.9	208.6	213.2	189.5	144.1	84.7	59.9
August	37.6	77.3	150.9	198.3	215.9	208.2	174.5	124.4	96.3
September	33.4	34.8	111.5	177.5	215.2	228.9	214.0	180.3	159.0
October	29.2	29.2	69.3	148.7	200.6	236.0	238.4	219.7	205.7
November	25.1	25.1	34.5	109.6	179.9	229.8	245.9	243.3	237.4
December	23.1	23.1	23.1	92.4	171.9	221.3	250.7	252.1	247.2

Month	SSW	SW	WSW	W	WNW	NW	NNW	HOR	Mult
January	248.7	253.4	227.6	185.5	112.8	32.5	24.6	187.8	1.00
February	225.2	245.4	245.7	212.8	146.5	75.2	28.2	226.4	1.00
March	184.3	219.7	241.7	227.4	181.7	120.1	36.5	259.0	1.00
April	128.0	178.6	218.0	225.2	199.7	154.2	82.1	275.1	1.00
May	86.4	146.3	196.6	217.3	208.4	174.5	113.6	278.7	1.00
June	70.8	132.3	185.4	210.2	210.6	181.0	124.1	277.0	1.00
July	83.9	143.3	191.2	210.6	206.9	173.0	112.5	274.0	1.00
August	123.0	171.8	210.0	217.2	193.2	150.1	81.7	268.9	1.00
September	180.5	214.2	228.3	218.9	176.0	106.8	37.6	252.2	1.00
October	219.9	238.9	235.1	202.4	149.0	67.9	29.2	224.4	1.00
November	244.5	246.7	229.5	176.5	112.9	32.6	25.1	188.9	1.00
December	252.8	249.6	223.6	165.3	98.8	23.1	23.1	172.3	1.00

Mult. = User-defined solar multiplier factor.

QUESTIONNAIRE (RESIDENTIAL BUILDING)
نموذج استبيان (مبنى سكنى)

A. GENERAL INFORMATION	معلومات عامة:
<u>Person in Charge:</u>	المدير المسئول
Name:	الاسم:
Tel. :	تليفون:
E-mail:	البريد الالكتروني:
B. BUILDING CONSTRUCTION	وصف المبنى:
1. Orientation: Facing	الاتجاه:
2. Total land Area (m^2):	اجمالي مساحة الارض (م2):
3. Total Living (Closed) Area (m2):	اجمالي مساحة المعيشة (م2):
4. Total Roof Area (m2):	اجمالي مساحة السطح (م2):
5. Number of Floors:	عدد الادوار:

6. External Opaque Wall Area (m2):			مساحة الحوائط الخارجية
7. Total Window Area (m2):	No. x Area of each window = …………………………		مساحة الشبابيك:
8. Window Glass Type:			زجاج الشبابيك:
9. Landscape Area (m2):			المساحة:
10. Swimming Pool Area (m2):			مساحة حمام السباحة:
11. Wall Insulation:	YES TYPE:	NO	عزل الحائط:
12. Roof Insulation:	YES TYPE:	NO	عزل السقف:
13. Window-to-wall Ratio (%):			نسبة مساحة النوافذ الى الحوائط:
14. Floor-to-floor Height (m):			ارتفاع السقف:
15. Occupancy:	……. Persons		عدد الافراد:

C. ENERGY CONSUMPTION:

ج . استهلاك الطاقة

Year:

السنة

Month	Electricity	Elec. Bill	N. Gas	Gas Bill
	(kWh)	(LE)	(m^3)	(LE)
الشهر	استهلاك الكهرباء	فاتورة الكهرباء	استهلاك الغاز الطبيعي	فاتورة الغاز الطبيعي
January				
February				
March				
April				
June				
July				
August				
September				
October				
November				
December				
Total				

D. AIR CONDITIONING SYSTEM

نظام التبريد والتكييف

Type: **الطراز:**

Central: مركزي		Package Air Cooled تبريد بالهواء	Chilled Water Cooling تبريد بالمياه
Rated Capacity: القدرة	Ton: Btu/hr:		
Split: منفصل	Qty: Capacity:		
Window: شباك	Qty: Capacity:		

Thermostat Setting: …… ^{0} C درجة الحرارة:

Average Daily Operating Hours: عدد ساعات التشغيل اليومية:

Heating in Winter: YES NO التدفئة في الشتاء

If YES - Heating Months ….. (November - February) ? شهور التدفئة

Heating of Swimming Pool:	YES	NO		تدفئة حمام السباحة
If YES - Energy Used:	Electricity OR Natural Gas		كهرباء غاز طبيعي	الطاقة المستخدمة للتدفئة
Any Solar Heating Used?	YES	NO		
If YES - For What?				

E. LIGHTING SYSTEM

Type	Qty	Rated Power (W)	Total Power (W)	Avg. Op. Hours	Comments (ملاحظات)
1. Lamps					
Incandescent (لمبة فتيلة عادية)		100			
Incandescent (لمبة فتيلة عادية)		60			
Fluorescent 1		40			
Fluorescent 2		20			
Halogen		---			
Others					
2. Ballast					
Magnetic					
Electronic					
3. Fixtures					
No. of Lamps					
Reflector				NO	
4. Dimmer					

F. END-USE EQUIPMENT

Equipment	Type	Qty	Size	Rated Power	Operating Hours	Remarks (ملاحظات)
				(W)		
Refrigerator						
Freezers						
Water Heater						

Washing Machine						
TV Set						
VCR/DVD						
Electrical Fans						
Vacuum Cleaner						
Electric Iron						
Computer + Printer						

Appendix to Ch 5

Apartment 1 Reception

1. General Details:
Floor Area .... **1000.0** ft²
Avg. Ceiling Height .... **9.0** ft
Building Weight .... **120.0** lb/ft²
1.1. OA Ventilation Requirements:
Space Usage .... **User-Defined**
OA Requirement 1 .... **2.60** CFM/ft²
OA Requirement 2 .... **20.0** CFM/person

2. Internals:
2.1. Overhead Lighting:
Fixture Type ..... **Recessed (Unvented)**
Wattage .... **0.80** W/ft²
Ballast Multiplier **1.08**
Schedule **Profile 5**
2.2. Task Lighting:
Wattage .... **0.20** W/ft²
Schedule .... **Task Lighting**
2.3. Electrical Equipment:
Wattage .... **0.50** W/ft²
Schedule .... **Profile 5**
2.4. People:
Occupancy .... **2** People
Activity Level .... **Seated at Rest**
Sensible .... **230.0** BTU/hr/person
Latent .... **120.0** BTU/hr/person
Schedule **Reception Schedule**
2.5. Miscellaneous Loads:
Sensible .... **0** BTU/hr
Schedule .... **None**
Latent .... **0** BTU/hr
Schedule **None**

3. Walls, Windows, Doors:

Exp.	Wall Gross Area (ft²)	Window 1 Qty.	Window 2 Qty.	Door 1 Qty.
N	484.0	2	2	0
E	323.0	2	0	0
W	480.0	2	1	0

3.1. Construction Types for Exposure N
Wall Type .... **Apartment Wall Assembly**
1st Window Type **Apt. Reception Window 2**
1st Window Shade Type **Default Shade Type**
2nd Window Type . **Apt. North, Window 2**
2nd Window Shade Type **Default Shade Type**

3.2. Construction Types for Exposure E
Wall Type .... **Apartment Wall Assembly**
1st Window Type .. **Apt. North, Window 1**
1st Window Shade Type **Default Shade Type**

3.3. Construction Types for Exposure W
Wall Type .... **Apartment Wall Assembly**
1st Window Type .. **Apt. North, Window 1**
1st Window Shade Type **Default Shade Type**
2nd Window Type . **Apt. North, Window 2**
2nd Window Shade Type **Default Shade Type**

4. Roofs, Skylights:

Exp.	Roof Gross Area (ft²)	Roof Slope (deg.)	Skylight Qty.
H	1000.0	0	0

4.1. Construction Types for Exposure H
Roof Type **Built-up Roof + 8" HW Concrete**

5. Infiltration:
Design Cooling .... **0.10** ACH
Design Heating .... **0.00** CFM
Energy Analysis .... **1.00** ACH
Infiltration occurs only when the fan is off.

6. Floors:
Type **Floor above Conditioned Space**
(No additional input required for this floor type).

7. Partitions:
7.1. 1st Partition Details:
Partition Type .... **Wall Partition**
Area .... **120.0** ft²
U-Value .... **0.500** BTU/(hr-ft²-°F)
Uncondit. Space Max Temp .... **75.0** °F
Ambient at Space Max Temp .... **95.0** °F

Uncondit. Space Min Temp .... **75.0** °F
Ambient at Space Min Temp .... **85.0** °F

7.2. 2nd Partition Details:
(No partition data).

<u>Traditional House Analysis</u>

1. General Details:
Floor Area .... **3100.0** ft²
Avg. Ceiling Height .... **9.0** ft
Building Weight .... **90.0** lb/ft²
1.1. OA Ventilation Requirements:
Space Usage .... **User-Defined**
OA Requirement 1 .... **20.0** CFM/person
OA Requirement 2 .... **7.20** CFM/ft²

2. Internals:
2.1. Overhead Lighting:
Fixture Type .... **Free Hanging**
Wattage .... **0.80** W/ft²
Ballast Multiplier **1.08**
Schedule .... **Lighting**
2.2. Task Lighting:
Wattage .... **0.20** W/ft²
Schedule .... **Lighting**
2.3. Electrical Equipment:
Wattage .... **0.10** W/ft²
Schedule .... **Electrical Eqpt**

2.4. People:
Occupancy .... **7** People
Activity Level .... **Seated at Rest**
Sensible .... **230.0** BTU/hr/person
Latent .... **120.0** BTU/hr/person
Schedule .... **People**
2.5. Miscellaneous Loads:
Sensible .... **0** BTU/hr
Schedule .... **None**
Latent .... **0** BTU/hr
Schedule .... **None**

3. Walls, Windows, Doors:

Exp.	Wall Gross Area (ft²)	Window 1 Qty.	Window 2 Qty.	Door 1 Qty.
NE	520.0	2	1	1
ESE	580.0	2	1	0
SW	520.0	2	0	1
WNW	580.0	2	1	1

3.1. Construction Types for Exposure NE
Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
2nd Window Type .... **Window 4**
2nd Window Shade Type **Default Shade Type**
Door Type .... **Door 1**

3.2. Construction Types for Exposure ESE
Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
2nd Window Type .... **Window 2**
2nd Window Shade Type **Default Shade Type**

3.3. Construction Types for Exposure SW
Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
Door Type .... **Door 1**

3.4. Construction Types for Exposure WNW
Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
2nd Window Type .... **Window 4**
2nd Window Shade Type **Default Shade Type**
Door Type .... **Door 1**

4. Roofs, Skylights:

Exp.	Roof Gross Area (ft²)	Roof Slope (deg.)	Skylight Qty.
H	1700.0	0	0

4.1. Construction Types for Exposure H
Roof Type ..... **Default Roof Assembly**

5. Infiltration:
Design Cooling .... **0.10** ACH
Design Heating .... **0.00** CFM
Energy Analysis .... **0.00** CFM
Infiltration occurs only when the fan is off.

6. Floors:
Type **Floor above Conditioned Space**
(No additional input required for this floor type).

7. Partitions:
(No partition data).

<u>Villa Analysis – Base Case</u>

1. General Details:
Floor Area .... **3358.0** ft²
Avg. Ceiling Height .... **10.2** ft
Building Weight .... **90.0** lb/ft²

1.1. OA Ventilation Requirements:
Space Usage .... **User-Defined**
OA Requirement 1 .... **20.0** CFM/person
OA Requirement 2 .... **7.40** CFM/ft²

2. Internals:

2.1. Overhead Lighting:
Fixture Type .... **Free Hanging**
Wattage .... **1.10** W/ft²
Ballast Multiplier **1.08**
Schedule .... **Lighting**

2.2. Task Lighting:
Wattage .... **0.20** W/ft²
Schedule .... **Lighting**

2.3. Electrical Equipment:
Wattage .... **0.20** W/ft²
Schedule .... **Electrical Eqpt**

2.4. People:
Occupancy .... **7** People
Activity Level .... **Sedentary Work**
Sensible .... **280.0** BTU/hr/person
Latent .... **270.0** BTU/hr/person
Schedule .... **People**

2.5. Miscellaneous Loads:

Sensible .... **0** BTU/hr
Schedule .... **None**
Latent .... **0** BTU/hr
Schedule .... **None**

3. Walls, Windows, Doors:

Exp.	Wall Gross Area (ft^2)	Window 1 Qty.	Window 2 Qty.	Door 1 Qty.
N	450.0	2	0	1
S	450.0	2	2	0
E	394.0	1	0	1
W	394.0	1	0	1

3.1. Construction Types for Exposure N

Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
Door Type .... **Door 1**

3.2. Construction Types for Exposure S

Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
2nd Window Type .... **Window 2**
2nd Window Shade Type **Default Shade Type**

3.3. Construction Types for Exposure E

Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
1st Window Shade Type **Default Shade Type**
Door Type .... **Door 1**

3.4. Construction Types for Exposure W

Wall Type .... **Default External Wall**
1st Window Type .... **Window 1**
Door Type .... **Door 1**

4. Roofs, Skylights:

Exp.	Roof Gross Area (ft²)	Roof Slope (deg.)	Skylight Qty.
H	1722.0	0	0

4.1. Construction Types for Exposure H
Roof Type .... **Roof Assembly**

5. Infiltration:
Design Cooling .... **0.50** ACH
Design Heating .... **0.00** CFM
Energy Analysis .... **0.00** CFM
Infiltration occurs at all hours.

6. Floors:
Type **Floor above Conditioned Space**
(No additional input required for this floor type).

7. Partitions:
(No partition data).

APPENDIX to Ch 7
APPLICATION OF AHP IN RANKING DSM OPTIONS

1. Steps for Applying AHP.

Saaty [1-4] developed the following steps for applying the AHP:

(i) Define the problem and determine its goal.
(ii) Structure the hierarchy from the top (the objectives) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.
(iii) Construct a set of pair-wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 1. The pair-wise comparisons are done in terms of which element dominates the other.
(iv) There are n(n-1) judgments required to develop the set of matrices in step (iii). Reciprocals are automatically assigned in each pair-wise comparison.
(v) Historical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
(vi) Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows :

$$\mathbf{CI = (\lambda\ max\text{-}n)/(n\text{-}1)}$$

Where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.
(vii) Steps (iii) – (vi) are preferred for all levels in the hierarchy.

Table 1
Par-wise Comparison for AHP Preferences [1-4]

Numerical Rating	Definition	Explanation
9	Extremely preferred	Evidence favouring this activity is of absolute affirmation
7	Very strongly preferred	An activity is strongly favoured and its dominance is demonstrated in practice
5	Strongly preferred	Experience and judgment suggest a strong favour over another
3	Moderately preferred	Experience and judgment slightly favour one over another
1	Equally preferred	Two activities contribute equally to the objective
2,4,6,8	Intermediate values	When compromise is needed

Table 2 - Average Random Consistency (RI) [1-4]

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The steps mentioned above could be implemented either automatically using software, or "Expert Choice", developed by Export Choice, Inc. [5], or manually as will be demonstrated as follows.

2. AHP for Identifying DSM Priority Options

In this research, Saaty method of AHP will be applied as follows:

Step 1: We completely define the problem and develop a hierarchy which will accurately represent the problem using the following guidelines:

Level 1 – Final goal:
Level 2 – Criteria used to judge alternatives

Level 3 – Alternatives
As shown in Figure 1, the goal is represented by high priority DSM option with optimum saved energy and peak demand reduction.
In level 2, six criteria are used to evaluate DSM options (alternatives), as shown in Table 3. Each criterion has five scores (weights). These weights are provided by DSM experts.

Figure1 – AHP Block Diagram

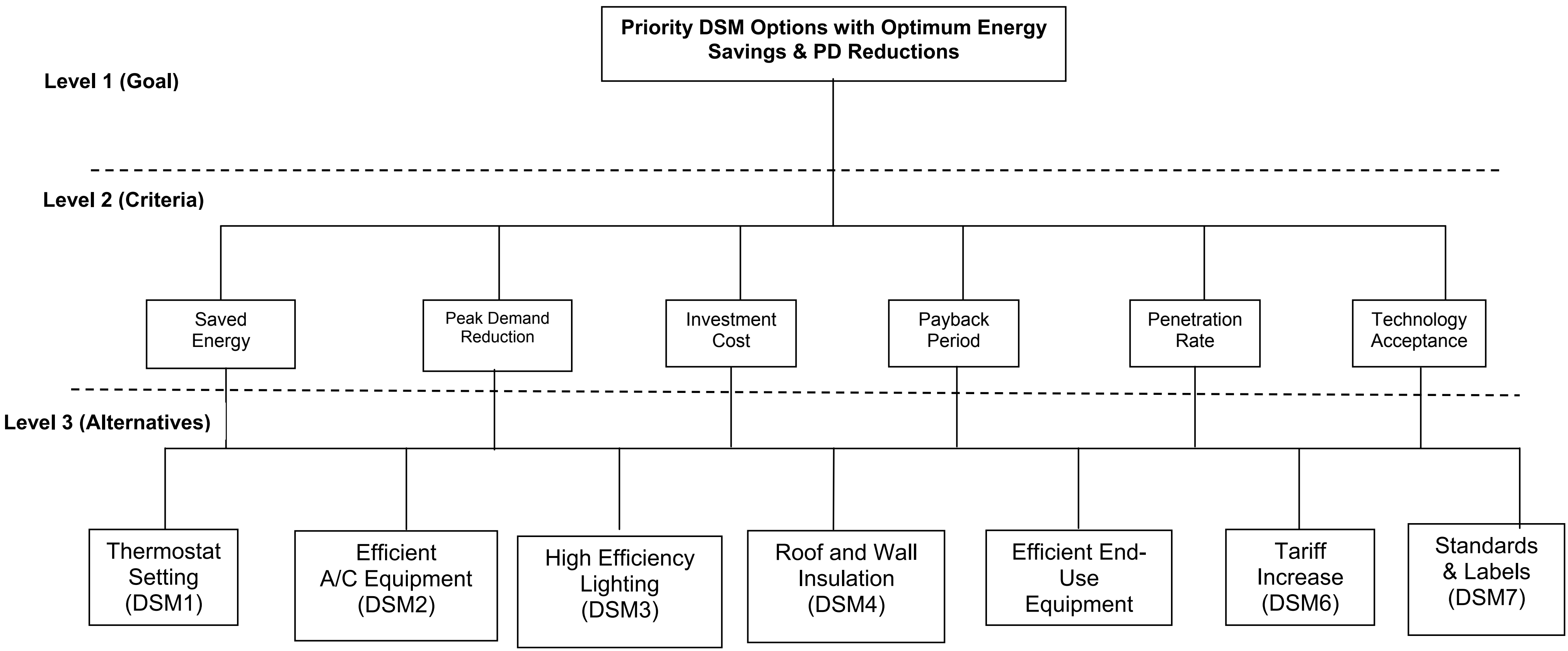


Table 3 – Six Criteria Used for DSM Evaluation

Criteria	Weight				
	1	3	5	7	9
1. Saved Energy	Very low (<10%)	Low (10-20%)	Medium (20-30%)	High (30-40%)	Very High (> 40%)
2. Peak Demand Reduction	Very low (<10%)	Low (10-20%)	Medium (20-30%)	High (30-40%)	Very High (> 40%)
3. Investment Cost	Very high cost	High cost	Medium cost	Low cost	No Cost/Very low cost
4. Payback Period	Very long (>5 yrs)	Long (4-5 yrs)	Medium (2-4 yrs)	Short (1-2 yrs)	Very short (< 1 yr)
5. Penetration Level	1 - 5% per year	5 – 10% per year	10 – 20% per year	20 – 30% per year	> 30% per year
6. Technology Acceptance	Low. Acceptance	Medium. Acceptance	High Acceptance	Very High Acceptance	Full Acceptance

The weights of each criterion are based on the experience of DSM experts.

<u>Step 2:</u>
The next step is to develop matrices that compare the criteria with themselves (within level 2) and the alternatives (DSM options) with each criterion (between level 2 and level 3). Pair-wise comparisons are needed to determine the relative importance of each ratings scale category (intensity). In the hierarchy shown in Figure 1, alternative are not pair-wise compared in a rating model, rather alternatives are rated for each criterion.
The pair-wise comparison matrix for the six criteria is developed in Table 4, in terms of importance of each in contributing to the overall goal. We notice in Table 4, the ones across the diagonal.

Table 4 - Pair-wise Comparison Matrix for the Six Criteria (With Column Totals)

	SE	PLR	IC	PBP	PR	TA	Priority Vector
SE	1.0	1.00 (9/9)	1.286 (9/7)	1.286 (9/7)	1.800 (9/5)	3.00 ((9/3)	**0.225**
PLR	1.00 (9/9)	1.0	1.286 (9/7)	1.286 (9/7)	1.800 (9/5	3.00 (9/3)	**0.225**
IC	0.778 (7/9)	0.778 (7/9)	1.0	1.0 (7/7)	1.400 (7/5)	2.333 (7/3)	**0.175**
PBP	0.778 (7/9)	0.778 (7/9)	1.0 (7/9)	1.0	1.400 (7/5)	2.333 (7/3)	**0.175**
PR	0.556 (5/9)	0.556 (5/9)	0.714 (5/7)	0.714 (5/7)	1.0	1.667 (5/3)	**0.125**
TA	0.333 (3/9)	0.333 (3/9)	0.429 (3/7)	0.429 (3/7)	0.600 (3/5)	1.0	**0.075**
SUM	**4.444**	**4.444**	**5.714**	**5.714**	**8.000**	**13.333**	**Σ=1.00**

SE = Saved Energy, PLR = Peak Load Reduction, IC = Investment Cost
PBP = Payback Period PR = Penetration Rate, TA = Technology Acceptance

Synthesizing the pair-wise comparison matrix is performed by dividing each element of the matrix by its column total. For example, the first value 0.225 in Table 5 is obtained by dividing 1 (from Table 4) by 4.444, the sum of the column items in Table 4 (1 + 1 + 0.778 + 0.778 + 0.556 + 0.333).

The priority vector in Table 5 can be obtained by finding the raw averages. Therefore, the priority vector for six criteria is given below.

$$\begin{bmatrix} 0.225 \\ 0.225 \\ 0.175 \\ 0.175 \\ 0.125 \\ 0.075 \end{bmatrix}$$

Table 5 – Synthesized Matrix for the Six Criteria

	SE	PLR	IC	PBP	PR	TA	Priority Vector
SE	0.225	0.225	0.225	0.225	0.225	0.225	**0.225**
PLR	0.225	0.225	0.225	0.225	0.225	0.225	**0.225**
IC	0.175	0.175	0.175	0.175	0.175	0.175	**0.175**
PBP	0.175	0.175	0.175	0.175	0.175	0.175	**0.175**
PR	0.125	0.125	0.125	0.125	0.125	0.125	**0.125**
TA	0.075	0.075	0.075	0.075	0.075	0.075	**0.075**
SUM	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Now we have to estimate the consistency ratio, by using the Eigen value as follows:

$$\mathbf{0.225}\begin{matrix}1.000\\1.000\\0.778\\0.778\\0.556\\0.333\end{matrix} + \mathbf{0.225}\begin{matrix}1.000\\1.000\\0.778\\0.778\\0.556\\0.333\end{matrix} + \mathbf{0.175}\begin{matrix}1.286\\1.286\\1.000\\1.000\\0.714\\0.429\end{matrix} + \mathbf{0.175}\begin{matrix}1.286\\1.286\\1.000\\1.000\\0.714\\0.429\end{matrix}$$

$$+ \mathbf{0.125}\begin{matrix}1.800\\1.800\\1.400\\1.400\\1.000\\0.600\end{matrix} + \mathbf{0.075}\begin{matrix}3.000\\3.000\\2.333\\2.333\\1.667\\1.000\end{matrix} = \begin{matrix}\mathbf{1.35}\\\mathbf{1.35}\\\mathbf{1.05}\\\mathbf{1.05}\\\mathbf{0.75}\\\mathbf{0.45}\end{matrix}$$

(Weighted sum matrix)

Dividing all the elements of the weighted sum matrices by their respective priority vector elements, we obtain:

1.35/0.225 = 6.00, 1.35/0.225 = 6.00, 1.05/0.175 = 6.00, 1.05/0.175 = 6.00
0.75/1.25 = 0.60, 0.45/0.075 = 6.00.

We then compute the average of these values to obtain the eigenvalue λ_{max}

$$\lambda_{max} = \frac{(6.00 + 6.00 + 6.00 + 6.00 + 0.60 + 6.00}{6} = 510$$

We now find the consistency index, CI, as follows:

Consistency Index		CI	=	(λ max-n)/(n-1)	= -0,18	
	Where	N	=		6	
According to Saaty:		Assume the random consistency for the size of matrix = 6			RI = 1.24	
Consistency Ratio		CR	=	CI/RI	-0.145	< 0.1

As the value of CR is less than 0.1, the judgments are acceptable.

In a similar manner, we have to indicate the preferences or priority for each alternative, or DSM, in terms of how it contributes to each criterion as shown in Table 6 for the saved energy (SE) criterion.

Table 6 - Pair-wise Comparison for Saved Energy

Saved Energy	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**
DSM1	1 (3/3)	(3/5)	(3/5)	(3/5)	(3/1)	(3/3)	(3/3)
DSM2	(5/3)	1 (5/5)	(5/3)	(5/5)	(5/1)	(5/3)	(5/3)
DSM3	(3/3)	(3/5)	1 (3/3)	(3/5)	(3/1)	(3/3)	(3/3)
DSM4	(5/3)	(5/5)	(5/3)	1 (5/5)	(5/1)	(5/3)	(5/3)
DSM5	(1/3)	(1/5)	(1/3)	(1/5)	1 (1/1)	(1/3)	(1/3)
DSM6	(3/3)	(3/5)	(3/3)	(3/5)	(3/1)	1 (3/3)	(3/3)
DSM7	(3/3)	(3/5)	(3/3)	(3/5)	(3/1)	(3/3)	1 (3/3)

Then synthesizing the pair-wise comparison and obtaining the priority vector as shown in Table 7. For example, the value of DSM1 with respect to the criterion ""Saved Energy" is 0.124 as shown in the Table.

Table 7 - Synthesized Matrix for "Saved Energy"

Saved Energy	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	0,130	0,130	0,083	0,130	0,130	0,130	0,130	**0,124**
DSM2	0,217	0,217	0,229	0,217	0,217	0,217	0,217	**0,219**
DSM3	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
DSM4	0,217	0,217	0,229	0,217	0,217	0,217	0,217	**0,219**
DSM5	0,043	0,043	0,046	0,043	0,043	0,043	0,043	**0,044**
DSM6	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
DSM7	0,130	0,130	0,138	0,130	0,130	0,130	0,130	**0,131**
SUM	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**

The consistency ratio is now calculated as before, giving the following results:

Consistency Index		CI	=	(λ max-n)/(n-1)	= -0,010	
	where	N	=	7		
According to Saaty:		Considering the random consistency for the size of matrix = 7			RI = 1.32	
Consistency Ratio		CR	=	CI/RI	-0,0073	< 0.1

Since the value of CR is less than 0.1, the judgments are acceptable. Similarly, the pair-wise comparisons matrices and priority vectors for the remaining criteria can be evaluated as shown in Tables 8-12, for "Peak Load Reduction", "Investment Cost", "Payback Period", "Penetration Rate" and "Technology Acceptance" respectively.

Table 8 - Pair wise Comparison for "Peak Load Reduction"

Peak Load Reduction	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	1 (3/3)	(3/3)	(3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,179**
DSM2	(3/3)	1(3/3)	(3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,179**
DSM3	(3/3)	(3/3)	1 (3/3)	(3/5)	(3/1)	(3/1)	(3/1)	**0,197**
DSM4	(5/3)	(5/3)	(5/3)	1 (5/5)	(5/1)	(5/1)	(5/1)	**0,267**
DSM5	(1/3)	(1/3)	(1/3)	(1/5)	1 (1/1)	(1/1)	(1/1)	**0,060**
DSM6	(1/3)	(1/3)	(1/3)	(1/5)	(1/1)	1(1/1)	(1/1)	**0,060**
DSM7	(1/3)	(1/3)	(1/3)	(1/5)	(1/1)	(1/1)	1(1/1)	**0,060**

Table 9 - Pair wise Comparison for "Investment Cost"

Investment Cost	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	1	(9/5)	(9/5)	(9/5)	(9/5)	(9/9)	(9/5)	**0,209**
DSM2	(5/9)	1	(5/5)	(5/5)	(5/5)	(5/9)	(5/5)	**0,116**
DSM3	(5/9)	(5/5)	1	(5/5)	(5/5)	(5/9)	(5/5)	**0,116**
DSM4	(5/9)	(5/5)	(5/5)	1	(5/5)	(5/9)	(5/5)	**0,116**
DSM5	(5/9)	1	(5/5)	(5/5)	1	(5/9)	(5/5)	**0,116**
DSM6	(9/9)	(9/5)	(9/5)	(9/5)	(9/5)	1	(9/5)	**0,209**
DSM7	(5/9)	(5/5)	(5/5)	(5/5)	(5/5)	(5/9)	1	**0,116**

Table 10 - Pair wise Comparison for "Payback Period"

Investment Cost	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	1	(9/7)	(9/5)	(9/5)	(9/3)	(9/7)	(9/3)	**0.231**
DSM2	(7/9)	1	(7/5)	(7/5)	(7/3)	(7/7)	(7/3)	**0.180**
DSM3	(5/9)	(5/7)	1	(5/5)	(5/3)	(5/7)	(5/3)	**0.128**
DSM4	(5/9)	(5/7)	(5/5)	1	(5/3)	(5/7)	(5/3)	**0.128**
DSM5	(3/9)	(3/7)	(3/5)	(3/5)	1	(3/7)	(3/3)	**0,077**
DSM6	(7/9)	(7/7)	(7/5)	(7/5)	(7/3)	1	(7/3)	**0,180**
DSM7	(3/9)	(3/7)	(3/5)	(3/5)	(3/3)	(3/7)	1	**0,077**

Table 11 - Pair wise Comparison for "Penetration Rate"

Penetration Rate	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	**1**	(5/5)	(5/1)	(5/1)	(5/1)	(5/3)	(5/1)	**0,294**
DSM2	(5/5)	**1**	(5/1)	(5/1)	(5/1)	(5/3)	(5/1)	**0,294**
DSM3	(1/5)	(1/5)	**1**	(1/1)	(1/1)	(1/3)	(1/1)	**0,059**
DSM4	(1/5)	(1/5)	(1/1)	**1**	(1/1)	(1/3)	(1/1)	**0,059**
DSM5	(1/5)	(1/5)	(1/1)	(1/1)	**1**	(1/3)	(1/1)	**0,059**
DSM6	(3/5)	(3/5)	(3/1)	(3/1)	(3/1)	**1**	(3/1)	**0,176**
DSM7	(1/5)	(1/5)	(1/1)	(1/1)	(1/1)	(1/3)	**1**	**0,059**

Table 12 - Pair wise Comparison for "Technology Acceptance"

Technical Acceptance	**DSM1**	**DSM2**	**DSM3**	**DSM4**	**DSM5**	**DSM6**	**DSM7**	**Priority Vector**
DSM1	1	(7/5)	(7/3)	(7/5)	(7/3)	(7/1)	(7/1)	**0,280**
DSM2	(5/7)	1	(5/3)	(5/5)	(5/3)	(5/1)	(5/1)	**0,200**
DSM3	(3/7)	(3/5)	1	(3/5)	(3/3)	(3/1)	(3/1)	**0,120**
DSM4	(5/7)	(5/5)	(5/3)	1	(5/3)	(5/1)	(5/1)	**0,200**
DSM5	(3/7)	(3/5)	(3/3)	(3/5)	1	(3/1)	(3/1)	**0,120**
DSM6	(1/7)	(1/5)	(1/3)	(1/5)	(1/3)	1	(1/1)	**0,040**
DSM7	(1/7)	(1/5)	(1/3)	(1/5)	(1/3)	(1/1)	1	**0,040**

Now, the Expert Choice software can do the rest automatically, or we manually combine the criterion priorities and the priorities of each alternative relative to each criterion in order to develop an overall priority ranking of the DSM options which is termed priority matrix (see Table 13).

Table 13 - Priority Matrix for DSM Options

	SE (0,225)	**PLR (0,225)**	**IC (0,175)**	**PBP (0,175)**	**PR (0,125)**	**TA (0,075)**	**Overall Priority Vector**
DSM1	0,124	0,179	0,209	0,231	0,294	0,280	**0,203**
DSM2	0,219	0,179	0,116	0,179	0,294	0,200	**0,193**
DSM3	0,131	0,197	0,116	0,128	0,059	0,120	**0,133**
DSM4	0,219	0,267	0,116	0,128	0,059	0,200	**0,175**
DSM5	0,044	0,060	0,116	0,077	0,059	0,120	**0,073**
DSM6	0,131	0,060	0,209	0,179	0,176	0,040	**0,136**
DSM7	0,131	0,060	0,116	0,077	0,059	0,040	**0,087**

The calculations for finding the overall priority of DSM options are given below for illustration purposes.

Overall priority of DSM1 = 0.225 (0.124) + 0.225 (0.179) + 0.175 (0.209) + 0.175 (0.231) + 0.125 (0.294) + 0.075 (0.280) = 0.203
The same sequence of calculations are carried out for the overall priority of DSM2, DSM3, DSM4, DSM5, DSM5 and DSM7, giving the values 0.193, 0.133, 0.175, 0.073, 0136 and 0.087.

Concluding the above AHP calculations we come to the following overall priority order of identified DSM options:

DSM1 (20.3%), DSM2 (19.3%), DSM4 (17.5%), DSM6 (13.6%), DSM3 (13.3%), DSM7 (8.7%) and DSM5 (7.3%).

References:

[1] Saaty TL, Analytic Hierarchy Process. New York: McGraw-Hill, 1980
[2] Saaty TL, Decision making for leaders. Belmont, California, 1985.
[3] Saaty TL, How to make a decision: The Analytic Hierarchy Process, The EU Journal of Operational Research, North-Holland, 1990.
[4] Saaty TL, Kearns KP, Analytical Planning the organization of systems. The analytic hierarchy process series, 1991, USA.

Appendix to Ch 8

Forecast of Private Dwellings

Year	Dwelling Stock									Grand Total
	Villas			Apartments			Traditional Houses			
	Existing	New	Total	Existing	New	Total	Existing	New	Total	
2006	104650	3983	108633	122666	0	122666	36500	1394	37894	**269193**
2007	108633	4468	113100	122666	4580	127246	37894	1394	39288	**279635**
2008	113100	2714	115815	127246	3512	130758	39288	330	39618	**286191**
2009	115815	2780	118594	130758	3609	134367	39618	333	39951	**292912**
2010	118594	2846	121441	134367	3709	138076	39951	336	40286	**299803**
2011	121441	2915	124355	138076	3811	141887	40286	338	40625	**306867**
2012	124355	2985	127340	141887	3916	145803	40625	341	40966	**314108**
2013	127340	3056	130396	145803	4024	149827	40966	344	41310	**321533**
2014	130396	3130	133525	149827	4135	153962	41310	347	41657	**329145**
2015	133525	3205	136730	153962	4249	158211	41657	350	42007	**336948**
2016	136730	3282	140012	158211	4367	162578	42007	353	42360	**344949**
2017	140012	3360	143372	162578	4487	167065	42360	356	42716	**353153**
2018	143372	3441	146813	167065	4611	171676	42716	359	43075	**361563**
2019	146813	3524	150336	171676	4738	176414	43075	362	43436	**370187**
2020	150336	3608	153944	176414	4869	181283	43436	365	43801	**379029**

1. Sharing by dwelling type is: 40% for villas, 46% for flats, and 14% for traditional houses.

2. Sharing by dwelling type is: 40% for villas, 46% for flats, and 14% for traditional houses.

Appendix 8.1

Electricity Demand Forecast in Kuwait (Baseline Scenario)

Year	Population	Installed Capacity (MW)	Peak Load (MW)	Generated Energy (GWh)	Load Factor (%)	Exported Energy[1] (GWh)	Final Elec. Consumption[2] (GWh)	Residential Sector (GWh)	Per Capita Consumption (kWh)	Max. Load Share / Capita (Watt)
2005	2244995	10189	8400	43734	59.43%	37906	33357	21682	16885	3742
2006	2328116	10229	8900	47605	61.06%	41570	36582	23778	17856	3823
2007	2410829	10655	9070	48761	61.37%	42422	37331	24265	17596	3762
2008	2498342	11082	9820	53476	62.16%	46524	40941	26612	18622	3931
2009	2589032	11736	10310	58011	64.23%	50470	44413	28869	19494	3982
2010	2683014	11914	10830	61660	64.99%	53644	47207	30684	19994	4037
2011	2780407	13914	11394	65829	65.95%	57271	50399	32759	20598	4098
2012	2881336	15414	11988	70529	67.16%	61360	53997	35098	21296	4161
2013	2985928	16316	12612	75565	68.40%	65742	57853	37604	22017	4224
2014	3094318	16838	13270	80960	69.65%	70435	61983	40289	22763	4289
2015	3206641	17377	13961	86741	70.93%	75465	66409	43166	23534	4354
2016	3323042	17933	14688	92934	72.23%	80853	71150	46248	24331	4420
2017	3443669	18507	15454	99570	73.55%	86626	76231	49550	25155	4488
2018	3568674	19099	16259	106679	74.90%	92811	81673	53088	26007	4556
2019	3698217	19710	17106	114296	76.27%	99437	87505	56878	26888	4625
2020	3832462	20341	17997	122457	77.67%	106537	93753	60939	27799	4696
AVG					68.12%					

Source: MEW, Statistical Year Book, 2006 (from 2005 to 2010, the rest by the author)

1. Exported energy = Generated energy - Consumption in power plants

2. Final energy consumption = Exported energy - Network T. & D. losses (12%)

Appendix 8.2

Forecast of Baseline End - Use Consumption of Selected Dwellings (Without any DSM Activities)

(Low Baseline Scenario)

Year	Annual Energy Stock (GWh)									Grand Total
	Villas			Apartments			Traditional Houses			
	Existing	New	Total	Existing	New	Total	Existing	New	Total	
2005	-	-	10777.8	-	-	4126.5	-	-	2608.8	**17513**
2006	10777.8	650.5	11428.3	4126.5	56.8	4183.4	2608.8	124.8	2733.7	**18345**
2007	11428.3	738.7	12167.0	4183.4	61.7	4245.1	2733.7	140.1	2873.7	**19286**
2008	12167.0	77.5	12244.5	4245.1	6.2	4251.2	2873.7	14.5	2888.2	**19384**
2009	12244.5	78.0	12322.5	4251.2	6.2	4257.4	2888.2	14.6	2902.8	**19483**
2010	12322.5	78.5	12401.0	4257.4	6.2	4263.6	2902.8	14.7	2917.5	**19582**
2011	12401.0	79.0	12480.0	4263.6	6.2	4269.8	2917.5	14.7	2932.2	**19682**
2012	12480.0	79.5	12559.4	4269.8	6.2	4276.0	2932.2	14.8	2947.0	**19782**
2013	12559.4	80.0	12639.4	4276.0	6.2	4282.2	2947.0	14.9	2961.9	**19884**
2014	12639.4	80.5	12720.0	4282.2	6.2	4288.4	2961.9	15.0	2976.8	**19985**
2015	12720.0	81.0	12801.0	4288.4	6.2	4294.7	2976.8	15.0	2991.9	**20088**
2016	12801.0	81.5	12882.5	4294.7	6.2	4300.9	2991.9	15.1	3007.0	**20190**
2017	12882.5	82.1	12964.6	4300.9	6.3	4307.2	3007.0	15.2	3022.2	**20294**
2018	12964.6	82.6	13047.2	4307.2	6.3	4313.4	3022.2	15.3	3037.4	**20398**
2019	13047.2	83.1	13130.3	4313.4	6.3	4319.7	3037.4	15.3	3052.8	**20503**
2020	13130.3	83.6	13213.9	4319.7	6.3	4326.0	3052.8	15.4	3068.2	**20608**

1. Sharing by dwelling type is: 40% for villas, 46% for flats, and 14% for traditional houses.

Appendix 8.3

Forecast of Baseline Dwellings Consumption (Without any DSM Activities)

Year	Annual Energy Stock (GWh)									Grand Total
	Villas			Apartments			Traditional Houses			
	Existing	New	Total	Existing	New	Total	Existing	New	Total	
2005	-	-	13879.9	-	-	4983.6	-	-	2856.0	**21719**
2006	13879.9	870.0	14749.9	4983.6	66.8	5050.4	2856.0	120.6	2976.6	**22777**
2007	14749.9	988.9	15738.8	5050.4	72.5	5122.9	2976.6	134.5	3111.1	**23973**
2008	15738.8	129.1	15867.9	5122.9	9.0	5131.9	3111.1	17.2	3128.3	**24128**
2009	15867.9	130.2	15998.0	5131.9	9.0	5140.9	3128.3	17.3	3145.6	**24284**
2010	15998.0	131.2	16129.3	5140.9	9.0	5149.9	3145.6	17.4	3162.9	**24442**
2011	16129.3	132.3	16261.6	5149.9	9.0	5158.9	3162.9	17.5	3180.4	**24601**
2012	16261.6	133.4	16395.0	5158.9	9.1	5168.0	3180.4	17.6	3198.0	**24761**
2013	16395.0	134.5	16529.5	5168.0	9.1	5177.1	3198.0	17.7	3215.7	**24922**
2014	16529.5	135.6	16665.1	5177.1	9.1	5186.2	3215.7	17.8	3233.5	**25085**
2015	16665.1	136.7	16801.8	5186.2	9.1	5195.3	3233.5	17.9	3251.3	**25248**
2016	16801.8	137.8	16939.6	5195.3	9.1	5204.4	3251.3	18.0	3269.3	**25413**
2017	16939.6	139.0	17078.6	5204.4	9.1	5213.5	3269.3	18.1	3287.4	**25579**
2018	17078.6	140.1	17218.7	5213.5	9.2	5222.7	3287.4	18.2	3305.5	**25747**
2019	17218.7	141.2	17359.9	5222.7	9.2	5231.8	3305.5	18.3	3323.8	**25916**
2020	17359.9	142.4	17502.3	5231.8	9.2	5241.0	3323.8	18.4	3342.2	**26086**

1.This Scenario of Baseline Consumption is based on the results of simulation

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Development of Installed Capacity, Peak Demand

and Generated Energy (2005 - 2011)

Year	2005(*)	2006(*)	2007(**)	2008(**)	2009(**)	2010(**)	2011(**)	Growth Rate (%)
Installed Capacity (MW)	10189	10229	10655	11082	11736	11914	13914	3.2
Generated Energy (GWh)	43734	47605	48761	53476	58011	61660	65829	7.14
Peak Load (MW)	8400	8900	9070	9820	10320	10830	11394	0.06
Annual Load Factor (%)	59.4	61.1	61.4	62.2	64.2	65.0	66.0	-0.13

Source: MEW, Statistical Year Book, 2007

(*) Actual values

(**) Estimated values

Table of Kuwait Baseline Scenario of Electricity Consumption and Demand Forecast

Year	2005	2010	2015	2020	Average Growth Rate (%)
Generated Energy (GWh)	**43734**	**61660**	**86741**	**122457**	**7.1%**
Final Energy Consumption (GWh)					
1. All Sectors	33357	47207	66409	93753	7.13%
2. Residential	21682	30684	43166	60939	7.13%
Peak Summer Demand (MW)					
1. All Sectors	8400	10830	13961	17997	5.80%
2. Residential	4200	5415	6980.5	8998.5	5.80%
Load Factor (%)	59.4%	65.0%	70.9%	77.7%	-0.883

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DSM Impacts by Type of Dwelling - Annual Energy Savings (GWh)

Year	Villas	Apartments	Tr. Houses	Total	% Residential	% Final En. Consumption
2010	1671.1	530.8	326.3	2528.2	9.19%	**5.36%**
2011	1655.9	524.8	323.4	2504.1	8.69%	**4.97%**
2012	1677.9	529.2	327.4	2534.6	8.39%	**4.69%**
2013	1711.5	537.3	333.6	2582.3	8.16%	**4.46%**
2014	1751.0	547.9	341.2	2640.2	7.96%	**4.26%**
2015	1805.3	562.6	351.5	2719.5	7.82%	**4.10%**
2016	1880.3	584.0	366.0	2830.3	7.77%	**3.98%**
2017	1964.8	608.6	382.4	2955.9	7.74%	**3.88%**
2018	2062.0	636.9	401.3	3100.2	7.74%	**3.80%**
2019	2161.9	664.6	420.3	3246.8	7.74%	**3.71%**
2020	2232.1	681.6	433.0	3346.7	7.61%	**3.57%**
Total	**20573.9**	**6408.5**	**4006.4**	**30988.8**		

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DSM Impacts by Type of Dwelling - Peak Demand Reductions (MW)

Year	Villas	Apartments	Tr. Houses	Total	% Of Overall Peak Load
2010	245.4	85.0	49.0	379.4	**3.5%**
2011	243.6	84.2	49.1	376.8	**3.3%**
2012	263.8	91.2	53.7	408.7	**3.4%**
2013	292.5	101.4	60.2	454.2	**3.6%**
2014	327.1	113.9	68.4	509.4	**3.8%**
2015	374.6	131.1	79.4	585.1	**4.2%**
2016	440.6	155.2	94.9	690.6	**4.7%**
2017	519.1	184.1	113.6	816.8	**5.3%**
2018	614.3	219.1	136.4	969.8	**6.0%**
2019	720.2	257.8	161.8	1139.7	**6.7%**
2020	810.0	290.1	183.2	1283.4	**7.1%**

Table of Accumulated DSM Savings (2010 - 2020)

Dwelling	Energy Savings (GWh)							
	DSM1	**DSM2**	**DSM3**	**DSM4 + DSM7**	**DSM5**	**DSM6**	**Total**	**Total with 0.8 D.F.**
Villas	1102.8	1166	531.3	72.8	137.3	22737.2	25747.4	**20598**
Apartments	431.2	349.2	86.1	0.1	12.8	7131.1	8010.5	**6408**
Tr. Houses	213.4	256.6	74.9	1.2	15.2	4446.7	5008	**4006**
Total	**1747.4**	**1771.8**	**692.3**	**74.1**	**165.3**	**34315**	**38765.9**	**31013**

D.F. = Diversity Factor

Diversity Factor, where (a 0.8 diversity means that the device in question operates at its nominal or maximum load level 80% of the time that its connected and turned on).

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Program Participants for Traditional Houses

Year	Dwellings Stock (Tr. Houses)			Program Participants							
	Existing	New	Total	DSM1(*)	DSM2(*)	DSM3	DSM4(1)	DSM5(2)	DSM6(3)	Total(4)	%
2010	37543	2403	39946	781	781	781	481	781	4693	6638	**16.62%**
2011	39946	2557	42502	711	711	631	511	631	4993	6551	**15.41%**
2012	42502	2720	45223	842	842	714	544	714	5313	7174	**15.86%**
2013	45223	2894	48117	1076	1076	850	579	850	5653	8068	**16.77%**
2014	48117	3079	51196	1434	1434	953	616	953	6015	9123	**17.82%**
2015	51196	3277	54473	1935	1935	1167	655	1167	6400	10608	**19.47%**
2016	54473	3486	57959	2713	2713	1460	697	1460	6809	12681	**21.88%**
2017	57959	3709	61669	3698	3698	1785	742	1785	7245	15162	**24.59%**
2018	61669	3947	65615	4921	4921	2208	789	2208	7709	18205	**27.74%**
2019	65615	4199	69815	6220	6220	2808	840	2808	8202	21679	**31.05%**
2020	69815	4468	74283	7177	7177	3477	894	3477	8727	24742	**33.31%**
Total				**31508**	**31508**	**16834**	**7348**	**16834**	**71757**	**140631**	

(1) Applied only for new buildings
(2) Combined with DSM7 (Labels and Standards)
(3) With a minimum elasticity of -0.1, the reduction in energy consumption is 12,5%.and peak demand 2% (with tariff increase 125%)-Existing Dwellings Only
(4) A diversity factor 80% is considered in the summation

Saved E.	**15.70%**	**16.60%**	**16.80%**	**24.20%**	**4.60%**	**12.50%**
Peak R.	**12.60%**	**23.20%**	**16.40%**	**18.70%**	**2.91%**	**2.00%**

Table 10.1 - Total Savings (Energy & Peak Demand) (2010 - 2019) By DSM Options and Type of Dwelling

DSM Option	ID	Energy Savings (GWh)				Peak Demand Reductions (MW)			
		Villa	Apartment	TR. House	**Total**	Villa	Apartment	TR. House	**Total**
Thermostat Resetting from 75 to 78 degree °F.	DSM1	857.0	256.0	165.0	**1278.0**	854.4	352.2	195.7	**1402.3**
Replacing Incandescent Bulbs to CFL	DSM2	906.0	271.0	174.0	**1351.0**	891.5	322.9	229.7	**1444.1**
Upgrade A/C Equipment to Efficient Units with EER ≥ 11	DSM3	390.0	111.0	73.3	**574.3**	600.4	207.5	113.6	**921.5**
High Quality Wall and Roof Insulation	DSM4	66.0	4.4	8.6	**79.0**	322.7	0.0	4.6	**327.3**
Use Energy Efficient End-Use Equipment (1)	DSM5	107.0	30.2	20.1	**157.3**	99.2	16.0	9.1	**124.3**
Tariff Increase	DSM6	20601.0	6477.0	4031.0	**31109.0**	253.8	100.5	65.0	**419.3**
Total		**22927.0**	**7149.6**	**4472.0**	**34548.6**	**3022.0**	**999.1**	**617.6**	**4638.7**

(1) Combined with DSM7 (Labels and Standards)