The Brattle Group

BRINGING DEMAND-SIDE MANAGEMENT TO THE KINGDOM OF SAUDI ARABIA

Final Report

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EXECUTIVE SUMMARY

Saudi Arabia's Energy Challenge

The Kingdom of Saudi Arabia (KSA) is experiencing rapid growth in electricity demand, with system peak load expected to increase at a rate of six percent per year over the coming decade.[1] Major investment in upgrades and expansion of the electrical grid are needed to keep up with this growth. In fact, there is an expectation that between SR 20 and 40 billion per year will be invested in the electrical infrastructure in the coming years if the projected growth in demand is not tempered.[2] Already, mandatory load curtailment events have been utilized in order to avoid large-scale blackouts. The problem is compounded by artificially low energy prices and a hot climate, both of which encourage more energy consumption.

Figure ES-1 illustrates the current projection of KSA peak demand, and how that forecast could change if the country were to implement a cost-effective portfolio of five demand-side management (DSM) programs to reduce consumption during peak hours of the day.[3] A similar concept would apply to overall energy consumption. DSM includes demand response (DR), energy efficiency (EE) and load management.

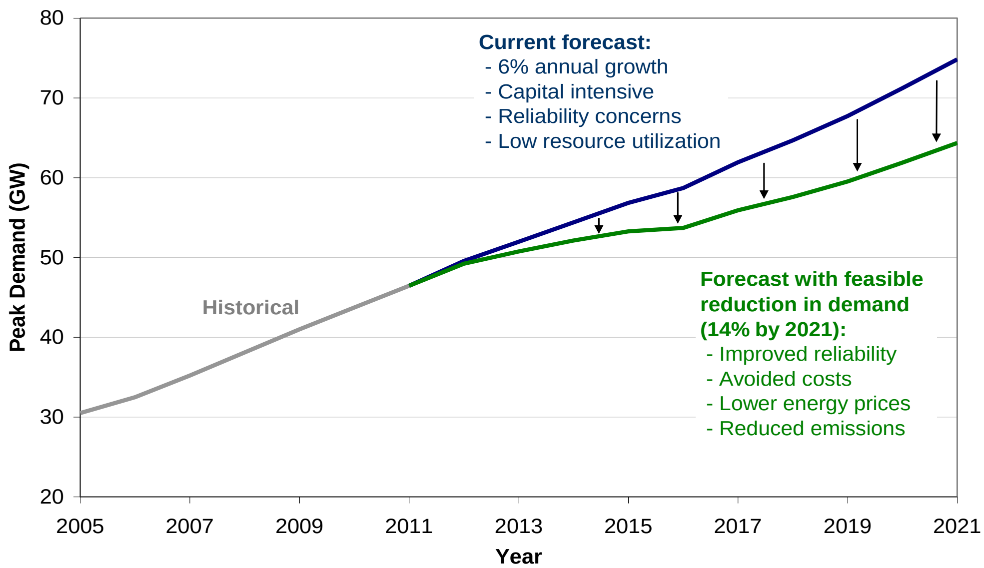

Figure ES-1: KSA System Peak Demand

Reductions in energy consumption not only during peak times, but during all hours of the day would also benefit the KSA. The impact of the proposed five program plan on energy consumption is illustrated in Figure ES-2.

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1 Derived from data provided in NEEP, 'National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A'

2 SEC and IPA estimates of required capital expenditure on generation, transmission, and distribution between 2011 and 2015. See IPA Energy + Water Economics, "Capital Costs Efficiency & Operational Expenditure Monitoring Study for Regulated Electricity Company, Volume 2 – Capex and Opex Review," prepared for ECRA, August 2010, p. 106.

3 The basis for these projections is discussed throughout this report.

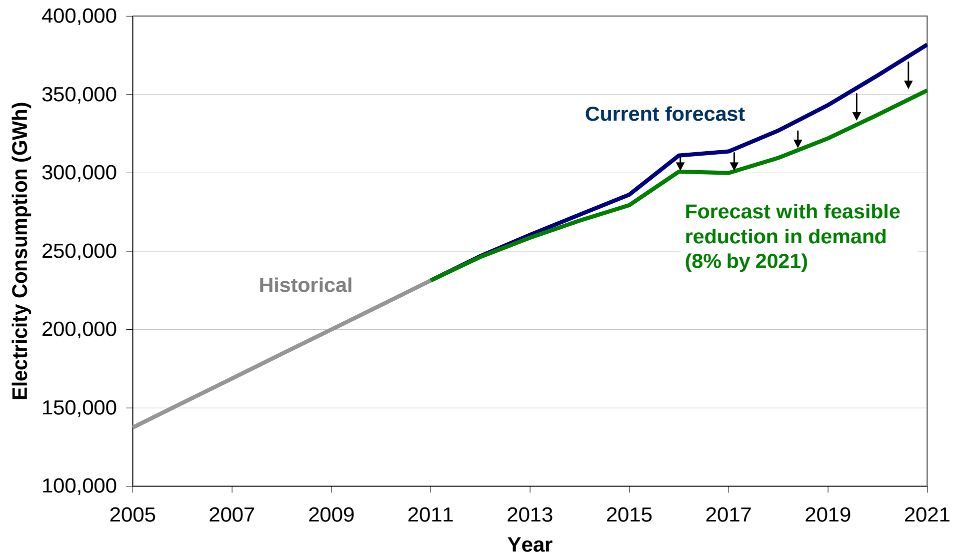

Figure ES-2: KSA Electricity Consumption Forecast

By encouraging reductions in electricity consumption during times of peak electricity demand, grid instability, or high supply costs, DSM measures have been shown to provide significant system benefits. In fact, even a five percent reduction in peak demand could lead to SR four billion in infrastructure cost savings to the KSA over the coming decade.[4] And with the additional impact of energy efficiency programs designed to reduce consumption during all hours of the year, the financial benefits to the KSA could be much higher.

To explore potential DSM opportunities and develop a program tailored to the specific needs of the KSA, the Electricity and Co-generation Regulatory Authority (ECRA) has commissioned *The Brattle Group* to lead a study focused on stakeholder education, program design, and implementation.

A Saudi Arabian Plan based on Global Best Practices

Our approach to developing a DSM plan for the KSA relied heavily on stakeholder input, which was gathered through an extensive series of in-person workshops, interviews, and conversations with the key parties that would be involved in DSM program implementation in the KSA. Insights from these conversations were complemented by the *Brattle* team's experience designing, implementing, and evaluating DSM programs for utilities and policymakers around the globe. Therefore, the program recommendations in this report are based on best practices from around the world, but tailored to the unique cultural and economic conditions of the KSA.

Our approach has the following features:

[4] Details on the development of this figure are provided in Chapter 5 of this report.

1) *Assessment of existing DSM efforts in the KSA*: The KSA's existing DSM programs were evaluated and critiqued against the backdrop of programs that have been offered successfully in other parts of the world.

2) *Identification of the applicable DSM measures to be evaluated for the KSA*: We assembled a comprehensive list of DSM measures being offered around the world, and based on a few basic screening criteria, arrived at the applicable measures to be considered for the KSA.

3) *Economic and impact assessment of each DSM measure*: Using the best available data about the likely impacts, costs, and benefits of each DSM measure, we developed an estimate of each measure's likely cost-effectiveness. We also developed an estimate of the feasible impact of each measure on system load (market potential). The results are the basis for our recommended DSM programs.

4) *Assessment of barriers to DSM in the KSA:* Based on interviews with stakeholders, we identified the key barriers that are preventing DSM activities from being expanded in the KSA. We then developed a plan for addressing these barriers through policy and market development.

5) *Development of implementation plans:* For the DSM programs that are recommended for full deployment in the short term, we developed implementation plans that include elements such as marketing strategies, budgets, schedules, and participation incentives.

The Five Pillars of DSM Implementation

History has shown that the success of any DSM program will eventually rest on the successful establishment of five key "pillars": goal-setting, funding, program execution, measurement and verification, and regulatory incentives. This is the foundation that must be laid for the KSA's DSM plan to achieve meaningful and significant impacts. To create these five pillars, we recommend 12 specific steps.[5]

[5] These recommendations are intended to serve as a blueprint for DSM implementation activities in the KSA. They should be interpreted as general guidelines for policy development. However, specific details, particularly as they relate to budget estimates, will need to be refined as program details are further developed.

Table ES-1: DSM Program Design and Implementation Recommendations

	Recommendation	Description
1.	**Objective Statement**	Develop a statement to reflect the goals of the program. For example: *The objective of this program is to induce more efficient consumption of electricity in the KSA, with a specific focus on reductions in consumption during times of high demand. These impacts will be integrated into system planning processes to result in lower necessary grid investment.*
2.	**Targets**	The DSM programs should aim to achieve 5,100 MW and 10,200 GWh of annual system-wide peak and energy reduction by 2016, and 10,500 MW and 29,200 GWh of annual reduction by 2021. By 2021, this would equate to 37% of projected load growth and 19% of projected energy growth
3.	**Funding Approval**	Establish a set of criteria which implementing entities must meet in order to receive funding. The criteria should be consistent with the objective of proving that costs are reasonable and that benefits are likely to outweigh the costs.
4.	**Dedicated DSM Funding**	A government entity should secure public funding for DSM program implementation. Illustrative estimates suggest that the annual amounts needed could be roughly SR 5.7 billion in 2016 and 4.2 SR billion in 2021.
5.	**Energy Awareness Campaign**	Develop and implement a nationwide energy awareness campaign that (1) has a message tailored to Saudi culture based on primary market research, (2) effectively describes to customers the need for energy reduction and ways to reduce consumption, (3) utilizes all feasible media channels, and (4) includes a measurement and verification plan to assess program effectiveness
6.	**Rebate Payments**	Deploy a portfolio of rebate-based DSM programs. In the short-term, this would include **direct load control**, and **curtailable load management**. Aspects of **cooling efficiency** and **new building efficiency** programs would also include rebate incentives.
7.	**Energy Quota Program**	To address very short-term emergency capacity shortage situations, the KSA should consider offering an energy quota program that provides payments to customers for achieving target reductions in monthly energy usage. However, when considering an energy quota program it is important to weigh the benefits against the potentially hefty rebate costs.
8.	**Codes & Standards**	Develop standards that specify a minimum level of efficiency for **cooling** and **new buildings**. Conduct a series of public workshops or hearings on these standards, with the objectives of (1)

		demonstrating the value of the standards in the KSA, (2) incorporating stakeholder feedback, and most importantly, (3) identifying the organization that will be accountable for enforcing the standards.
9.	**Energy Efficiency City**	To encourage the maturation of the DSM technology market in the KSA, consider funding the development of a city that can be used to demonstrate the benefits of energy efficiency. Develop the city through partnerships with a wide range of interested stakeholders, including smart grid technology manufacturers.
10.	**Cost-based Electric Rates**	Modify the existing tariff for all customer segments to reflect the true cost of electricity. Modifications should reflect the international market price of energy and the time-varying nature of electricity costs. Rates should be piloted before being fully deployed. For short-term deployment, **interruptible tariffs** should be offered on a voluntary basis to encourage peak load reductions.
11.	**Regulatory Incentives**	Establish a mechanism for publicly financing the implementation costs of utility DSM programs. Also consider establishing a decoupling mechanism, which removes the link between the utilities' sales and revenue to eliminate disincentives to pursue DSM. Explore the attractiveness of a shareholder incentives mechanism with stakeholders.
12.	**Measurement & Verification Protocols**	The KSA should establish M&V protocols for evaluating the impacts of DSM programs and incorporating them into system planning. These protocols will represent a standardized list of reporting requirements to be followed by the organizations conducting the M&V analysis. The product of the M&V analysis should be annual reports that document the progress of the programs relative to key performance indicators (peak and energy reductions) and document lessons learned during program implementation. The KSA should also establish a load research program, which would improve future DSM planning efforts.

Rising to the Challenge

Who will be responsible for developing and implementing these recommendations? Success will require the collective dedicated effort of several organizations within the KSA. For the DSM plan to be a success, each organization will need to be held accountable for specific aspects of implementation. They key proposed roles for each organization are:

- *Ministry of Water and Electricity (MOWE):* Secure funding for all DSM activities and organize a national energy awareness campaign

- *Electricity and Co-Generation Regulatory Authority (ECRA):* Oversee DSM implementation activities, modify regulatory framework to encourage DSM adoption, adopt a new long-term plan requiring expanded DSM activity, and provide independent measurement & verification of program impacts

- *Saudi Electricity Company (SEC) / Marafiq:* Build and invest in LM/DR capabilities and expertise, implement LM/DR programs, and collaborate in implementing efficiency awareness

- *Saudi Arabian Standards Organization (SASO):* Both develop and enforce new EE codes and standards

- *Saudi Energy Efficiency Center (SEEC):* Administer all EE program development and implementation and promote EE activities

Effective coordination across these organizations will result in DSM programs that will deliver significant benefits to Saudi Arabia. At current energy prices in the KSA, these programs could deliver net financial benefits of nearly SR 3 billion over the next decade, in the form of avoided energy and capacity costs. However, the true benefits of electricity consumption are even higher than this in the KSA, where every barrel of avoided domestic oil consumption results in a much higher payment for that same barrel on the international market.[6] Factoring this into the calculation, the net benefits could be as high as SR 50 billion over the next decade. This is summarized in Figure ES-3.

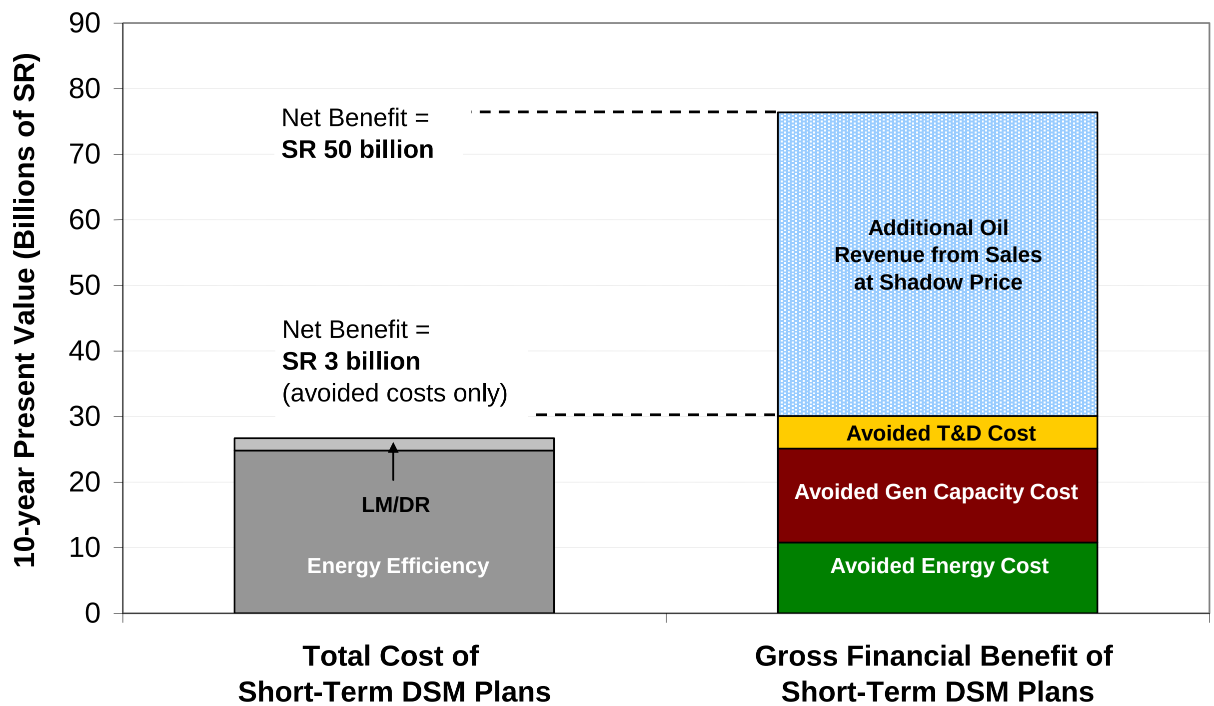

Figure ES-3: Costs and Benefits of Proposed DSM Programs in the KSA (10-year Present Value)

6 The shadow price of energy is assumed to be 5.3 times higher than the actual domestic price, based on information provided by ECRA. This appears to be a conservative estimate, since the world price of oil, currently at $100/barrel, would suggest a multiple of 20.

In addition to these financial benefits, the proposed DSM programs would also provide environmental benefits - something that could become increasingly valuable as global political pressure continues to build around reducing carbon dioxide emissions. Over the ten year lifetime of these programs, it is estimated that more than 38 billion tones of carbon emissions could be saved. By 2021, the annual reduction in carbon emissions would be approaching eight percent per year relative to the baseline forecast.

There would also be a direct financial benefit to SEC from these programs. Currently, even at discounted domestic oil prices, SEC is selling electricity at a rate that is below its costs. Therefore, in addition to the loss to the Saudi economy that is associated with selling oil at domestic prices, it is also the case that there is a loss to SEC associated with inefficient electricity consumption. Assuming that, on average, SEC is losing four halalas on every kilowatt-hour of electricity that it sells, the DSM programs are projected to avoid SR 2.6 billion (present value) in financial losses to the utility over the next decade.[7]

These benefits are contrasted against relatively moderate program costs. The costs of the programs are, from the perspective of the party implementing the programs, largely driven by incentives and cash rebates that are used to encourage customer participation. This is particularly true of the energy efficiency programs. Providing customers with an incentive to participate will be key to the success of the program, particularly in the early stages when customer awareness is low.

The DSM programs presented in this report represent an opportunity for the KSA to improve system reliability, reduce unnecessary capital investment in grid infrastructure, increase national profits from international oil sales, improve overall economic efficiency, and reduce harmful environmental emissions. However, this study should mark the beginning rather than the end of DSM activity in the KSA. Rapid implementation of these programs is the key next step towards a sustainable energy future in Saudi Arabia for the coming decade.

[7] Estimate of rate deficiency is based on informal conversations with SEC staff. Avoided financial losses are calculated by multiplying 4 hh/kWh into the annual energy savings from the DSM programs, and discounting using a 10% annual rate.

1. INTRODUCTION

1.1. PROJECT BACKGROUND AND OBJECTIVE

The Kingdom of Saudi Arabia (KSA) is experiencing rapid growth in electricity demand, with system peak load expected to increase at a rate of six percent per year over the coming decade.[8] Major investment in upgrades and expansion of the electrical grid are needed to keep up with this growth. In fact, there is an expectation that between SR 20 and 40 billion per year will be invested in the electrical infrastructure in the coming years if the projected growth in electricity consumption is not tempered.[9] Already, mandatory load curtailment events have been utilized in order to avoid large-scale blackouts. And the problem is compounded by artificially low energy prices and a hot climate, both of which encourage more energy consumption rather than less. Figure 1-1 illustrates the current projection of KSA peak demand, and how that forecast could change if the country were to find feasible ways to encourage reductions in consumption during peak hours of the day.[10]

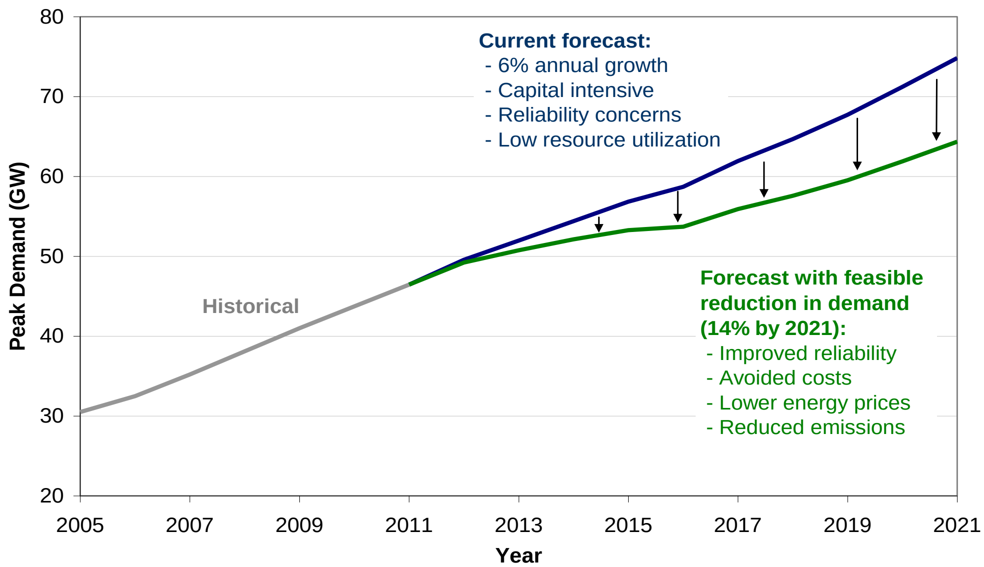

Figure 1-1: KSA System Peak Demand Forecast

Reductions in consumption not only during peak times, but during all hours of the day would also benefit the KSA. A similar forecast of feasible energy reductions is illustrated in Figure 1-2.

8 Derived from data provided in NEEP, 'National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A'

9 SEC and IPA estimates of required capital expenditure on generation, transmission, and distribution between 2011 and 2015. See IPA Energy + Water Economics, "Capital Costs Efficiency & Operational Expenditure Monitoring Study for Regulated Electricity Company, Volume 2 – Capex and Opex Review," prepared for ECRA, August 2010, p. 106.

10 The basis for these projections is discussed throughout this report.

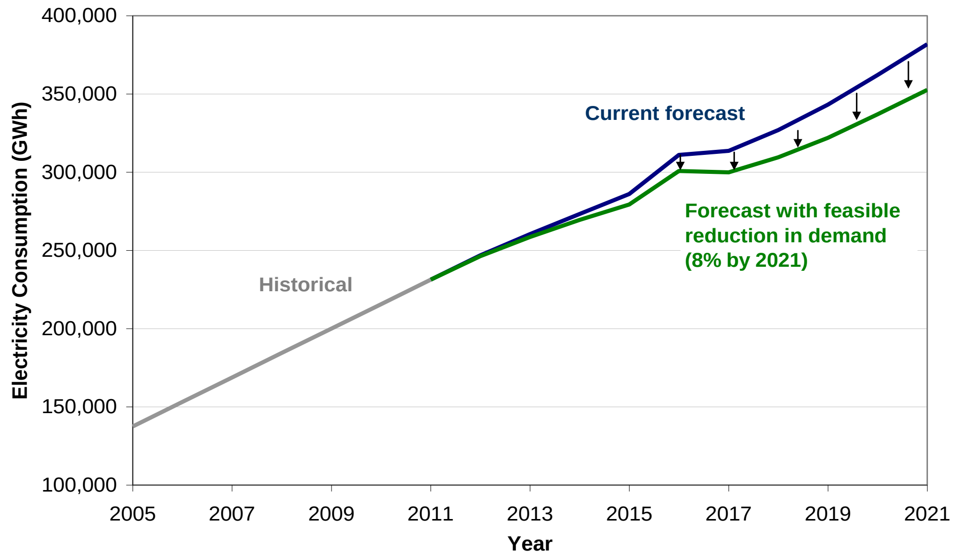

Figure 1-2: KSA Electricity Consumption Forecast

In recognition of the fact that the current situation of rapid demand growth and low energy awareness simply is not sustainable, stakeholders in the KSA are searching for new and effective ways to meet the nation's power needs. One potentially powerful set of tools in the KSA's future portfolio of energy resources is demand side management (DSM), which consists of load management (LM), demand response (DR), and energy efficiency (EE). By encouraging reductions in electricity consumption during times of peak electricity demand, grid instability, or high supply costs, DSM measures have been shown to provide significant system benefits. To explore potential DSM opportunities and develop a program for the KSA, the Electricity and Co-generation Regulatory Authority (ECRA) has commissioned *The Brattle Group* to lead a study focused on stakeholder education, program design, and implementation.

ECRA has defined several key activities or issues to be addressed in the project. These are paraphrased from the project Terms of Reference as follows:

1. Conduct a workshop and interviews with key stakeholders to provide an overview of DSM issues
2. Review DSM programs in six international countries or regions
3. Review and critique DSM methods currently in practice in the KSA
4. Describe the various DSM options and their drivers for implementation
5. Analyze existing DSM methods in the KSA for their practical viability, legal/policy implications, and potential future grid impacts
6. Identify the likely price responsiveness of various customer segments
7. Prioritize DSM options based on their expected impacts and applicability and economic attractiveness to the KSA
8. Identify barriers to implementation of the DSM options

9. Quantify the potential benefits of DSM options in the KSA
10. Suggest amendments to various legal, regulatory, or other codes that would aid in the implementation of DSM programs
11. Identify important roles for each major stakeholder in implementing the DSM programs
12. Develop a timeline and implementation schedule for the DSM programs
13. Identify methods for monitoring the development/implementation of the DSM programs and suggest corrective measures in case of deviation from expected results
14. Involve service providers and other stakeholders throughout this process

The development of this study has heavily involved stakeholder input and feedback. A two-day workshop on DSM issues was conducted by the *Brattle* team in Riyadh on December 11 and 12, 2010. This workshop served the dual purpose of educating stakeholders about the fundamental issues in DSM program design and implementation, and also provided the *Brattle* team with stakeholder perspectives on what is likely to work or not work in the KSA. The two-day workshop was then followed with three days of interviews with individual stakeholders to further discuss these issues, as well to as identify potential sources of data for this project. Follow-up meetings with stakeholders have supplemented that initial visit.

The *Brattle* team then presented preliminary findings in Riyadh in the form of an Interim Report in early March 2011. The Interim Report addressed the first seven project activities identified above and was used to collect feedback from executives and staff representatives from the major industry stakeholders. The conclusions of the Interim Report were modified accordingly to reflect this feedback.

The purpose of this Final Report is to combine the insights from these stakeholder conversations with the *Brattle* team's knowledge and understanding of global best practices in DSM program design to provide a roadmap for DSM activities in the KSA. The report provides not only recommendations for the types of programs that should be offered in the KSA, but also establishes a blueprint for implementing the programs and rolling them out to customers.

1.2. Overview of Methodology

The focus of this report is to arrive at recommendations for the most attractive DSM programs that could be considered in the KSA for full-scale deployment or pilot testing, and then establish a plan for implementing those programs. To provide context for this analysis, we first present examples of a wide variety of DSM programs that have been used effectively in other countries around the globe. This is supplemented both with a review and critique of ongoing DSM activities in the KSA, and an estimate of feasible target levels of peak demand reductions through an assessment of Saudi Arabia system load data. Ultimately, these elements of the report provide useful background for what is the core of our analysis – estimating the potential peak impact of each measure and its relative economic attractiveness.

Our approach to the measure analysis is sequential in nature. First, we identify the universe of possible measures to be included. Given the relatively limited experience with demand-side activities in the KSA, we have taken a very broad approach to avoid excluding any measure that may be of interest, other than those that are clearly not applicable in the KSA. Descriptions of each measure are provided to give a sense for the similarities and differences in their design features.

Then, cost, impact, and benefit estimates are developed for each measure and are tailored to Saudi-specific system conditions whenever possible. With this information, a benefit-cost ratio is developed for each measure of interest, to illustrate the relative economic attractiveness of each option. We refer to this as an economic screening analysis. Some measures will be found to be highly cost-effective and others will present significant economic barriers to adoption.

In addition to the economic screening analysis, we also quantify the potential size of each measure in terms of its impact on peak demand and energy sales. This analysis is based on assumptions about the highest achievable participation rates, which are derived from a review of global best practices for each measure. As such, the "market potential" estimates that we develop represent feasible estimates of the measure impacts, given the existing market conditions.

From the economic screening and the market assessment we are able to draw basic conclusions about the measures that are most attractive candidates for full-scale deployment and pilot testing in the KSA. Generally, measures with high benefit-cost ratios and an established history of international acceptance tend to be attractive for large scale deployment. Measures with significant potential but also significant uncertainty around their potential impacts and acceptance are candidates for pilot testing, to reduce this uncertainty. Other measures may be attractive for specific sub-segments of customers, or as demonstration projects (if there is an expectation for technological or cost improvements), but they are less likely to be "quick wins" from an implementation perspective.

Then we address the question of how to go about implementing the selected LM/DR/EE measures. First, the measures are grouped into programs that would allow for economies of scope and scale during implementation. Then, we identify the current barriers to DSM adoption in the KSA and the five keys to overcoming these barriers (goal-setting, funding, program execution, measurement and verification, and regulatory incentives). This is followed with the development of detailed implementation plans for each program (including information such as estimates of achievable impacts, timeline, budget, marketing strategy, and participation incentives). These plans are developed for short-, medium-, and long-term opportunities.

This methodological approach is illustrated in Figure 1-3.

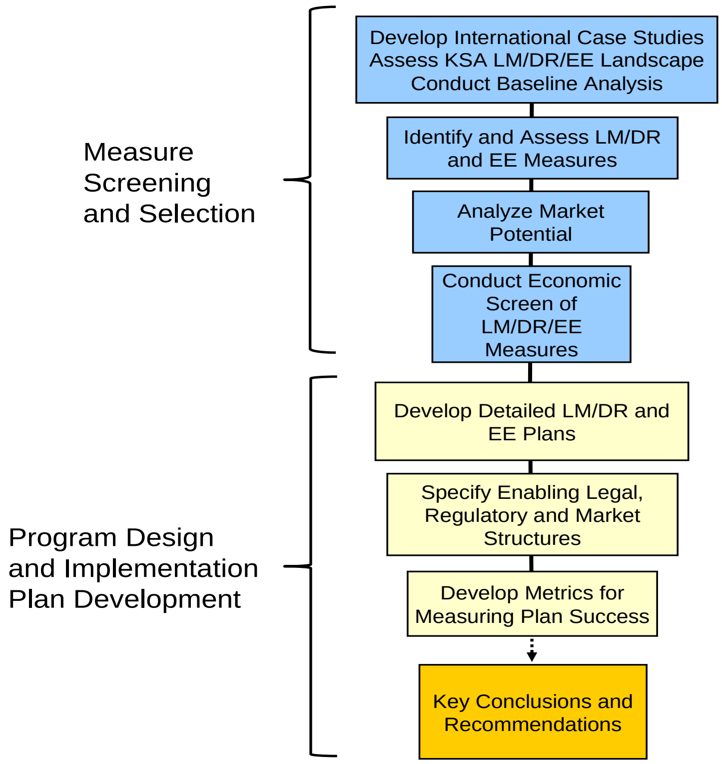

Figure 1-3: Methodological Approach to DSM Plan Development

1.3. DEFINING DSM

DSM has taken on different meanings in different contexts, so it is important to define the term specifically for the purposes of this project. In this report, DSM is an umbrella term that encompasses measures that produce reductions in electricity consumption during (but not limited to) "peak" times of the day, when demand for electricity is high and the marginal cost of providing that electricity is also often high.[11] There are sub-categories within this broad definition of DSM programs, depending on the specific characteristics of each measure:

Demand Response (DR) / Load Management (LM): LM/DR refers to the measures that are designed to reduce consumption during the 50 or 100 hours of the year with the highest load. DR programs are event-based, meaning that customers do not know far in advance when the load reductions will be needed. Typically, LM/DR programs provide between one day and one hour of advance notification for an event. When triggered for reliability conditions, the programs are usually called LM and when triggered for economic conditions they are typically called DR. However, the terms are increasingly being used interchangeably in the industry.

Permanent load shifting (PLS): PLS refers to measures that facilitate reductions during peak hours on most days of the year. In contrast to DR measures, which typically encourage reductions during 10 or 20 days of the year, PLS measures typically target all weekdays, or even

[11] A "measure" refers to a single DSM option that is offered to a single customer segment. Like measures are typically grouped into "programs" for coordination during implementation.

all days of the summer or year. Hence, PLS measures are "permanent" in the sense that the peak load reductions they are designed to produce will occur during on all or most days, rather than just during a limited number of events.

Information: There is also a group of measures that provide customers with information about their electricity consumption behavior. The principle behind these measures is to encourage customers to become more efficient consumers of electricity by equipping them with actionable knowledge that they otherwise would not have had. Some information measures have informally been found to lead to greater reductions during peak periods than during off peak periods, since this is when residential customers are most active and therefore more likely to make behavioral changes to their electricity usage patterns.[12] However, these measures typically produce a reduction in energy use during a greater number of hours than DR or PLS programs.

Energy efficiency (EE): Energy efficiency refers to the group of measures/ mechanisms that are not necessarily designed with the specific goal of reducing consumption during peak times, but rather have a primary objective of reducing overall consumption regardless of the timing. EE measures, or efficient energy-consuming equipment, save energy by providing the same service with a lower energy requirement. However, many energy efficiency measures do in fact provide peak load reductions, in addition to reductions during many other hours of the year. The most applicable EE measures for KSA that provide peak reductions have also been included in our analysis.

Figure 1-4 illustrates the various ways in which the load shape can be modified through demand-side programs. The highlighted illustrations are those that are consistent with the above descriptions and were therefore considered in this analysis.

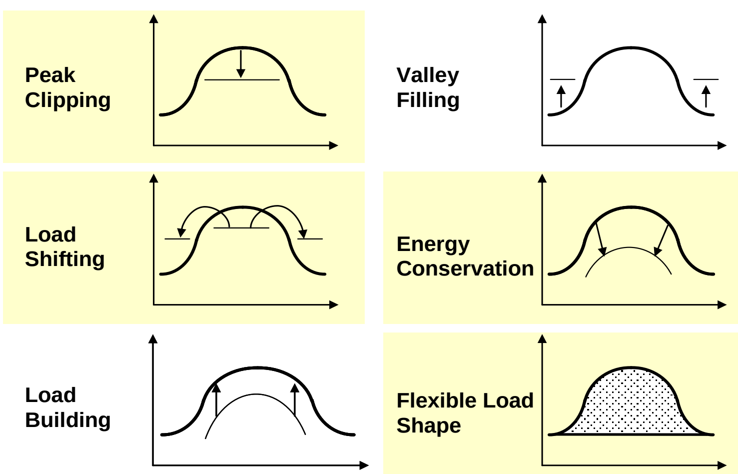

Figure 1-4: Load Shape Impact Options through DSM

Specific descriptions of each type of DSM measure considered in our analysis are provided in Chapter 6 of this report.

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[12] This is based on a confidential conversation with one information service provider. Limited empirical evidence currently exists on this specific issue.

1.4. ORGANIZATION OF REPORT

The rest of the report is organized as follows.

Chapter 2 provides context for the analysis by summarizing DSM activities around the globe. This includes a basic overview of current activities in six countries, followed by a summary of key insights from this survey for the KSA.

Chapter 3 is an overview of the current landscape of DSM activity in the KSA. It includes a description of the ongoing activities by the Saudi Electricity Company (SEC), large industrial programs, and initiatives that are under the supervision of the Saudi Energy Efficiency Center (SEEC).

Chapter 4 is a summary of the "baseline" data that is used in our analysis. This includes a snapshot of regional peak load, sales, and number of customers by segment, as well as projections of these variables into the future. The chapter also includes information on end-use appliance saturations, hourly load profiles, and marginal costs that could be avoided through DSM programs.

Chapter 5 is an assessment of the feasibility of DSM programs to effectively reduce peak load in the KSA. It includes historical analysis of demand conditions in the major utility operating areas as well as a quantification of the financial benefits that could result from a feasible reduction in peak load.

Chapter 6 is a description of the various DSM measures that could be pursued in the KSA. It includes not only a description of the measures, but also a characterization of the qualities that make each unique.

Chapter 7 is an analysis of the economic attractiveness and potential impact of each DSM measure. This analysis leads to preliminary insights about the measures that may be desirable to offer in the KSA.

Chapter 8 is a description of how the DSM measures are grouped into programs. It highlights the key features of each program and why it is or is not recommended for deployment in the short-, medium-, or long-term.

Chapter 9 describes the major barriers to DSM implementation and adoption in the KSA, as identified in workshops and interviews with industry stakeholders.

Chapter 10 presents the five keys to overcoming the barriers to DSM and fully enabling its deployment in the KSA. The result is five "pillars" of DSM enablement including goal-setting, funding, program execution, measurement and verification, and regulatory incentives. The five pillars are accompanied by recommendations for implementation.

Chapter 11 provides recommendations for organizational roles and responsibilities when implementing the DSM programs. It identifies several options for establishing accountability for various aspects of implementation among the key stakeholder groups.

Chapter 12 is a series of detailed implementation plans for the DSM programs that are recommended for short-term full-scale deployment. It includes guidelines around budget, timeline, participation incentives, marketing strategy, market potential, and cost-effectiveness.

Chapter 13 is an overview of the DSM programs for medium-term deployment. Most of these programs are recommended for pilot testing, so the chapter includes guidelines for successfully developing and implementing experimental pilots.

Chapter 14 is an overview of the DSM programs that should be re-evaluated in the long term. It provides a description of the program and identifies key issues and questions to be considered when re-evaluating the programs in the future.

Chapter 15 highlights the key consultant findings and recommendations that have arisen from this study.

2. INTERNATIONAL CASE STUDIES

LM/DR programs have a long and established history as resources for meeting peak demand in regions around the globe. However, there are significant differences in the reasons that each region has pursued LM/DR, the types of programs that each region has in place, and the policies that are used to promote LM/DR implementation. Understanding the reasons for these differences - and what that means for the KSA - will help ECRA and other stakeholders make informed decisions as the country moves forward with implementing its own LM/DR plan.

To understand the nature of LM/DR activity around the globe, case studies have been assembled for six different regions: China, United States (California), Brazil, Australia, South Korea, and Italy. These regions were chosen because of the diversity in their approach and experience with LM/DR. While each of these regions presents similarities and differences relative to the situation in the KSA, their experience with LM/DR programs and policy provides valuable insight and lessons learned that can guide the development of forward-looking energy policies in the Kingdom. A profile of each region (including the KSA for comparison) is provided in Table 2-1.

Table 2-1: Key Statistics for the Six Case Study Regions

	China	California	Brazil	Australia	S. Korea	Italy	Saudi Arabia
GDP							
GDP (2009), current US dollars, millions	$4,985,000	$1,891,400	$1,573,000	$924,843	$832,512	$2,111,000	$369,179
GDP per capita (2009), current US dollars	$3,744	$51,119	$8,119	$42,279	$17,078	$35,054	$14,540
Annual GDP Growth (2009)	9.10%	-1.56%	-0.19%	1.29%	0.20%	-5.04%	0.15%
Population							
Population (2009), millions	1,331.5	37.0	193.7	21.9	48.7	60.2	25.4
Annual Population Growth (2009)	0.51%	0.56%	0.91%	2.05%	0.29%	0.65%	2.33%
Energy							
Electricity Generation Capacity (2008), million kW	797	66	104	56	80	99	39
Net Electricity Consumption (2008), billion kWh	3,017	268	420	225	402	315	174
Per Capita Electricity Consumption (2008), kWh	2,277	7,291	2,168	10,303	8,248	5,223	6,872

Sources: Google Public Data Explorer, World Bank, U.S. Energy Information Administration, U.S. Census Bureau, U.S. Bureau of Economic Analysis

For each case study, we provide a brief overview of LM/DR activity in the region. This is followed by a discussion of key implications for the KSA that have been derived from this survey. Note that details for each of the six case studies, including existing LM/DR policies and regulations, as well as program impacts, are provided in Appendix A.

Energy efficiency is another option that may be valuable for reducing peak demand in the KSA. To provide a similar global perspective on energy efficiency policies and programs, the end of this chapter includes a sidebar synthesizing findings from recent research in this area.

2.1. SUMMARIES OF THE INTERNATIONAL CASE STUDIES

China

China has taken its first steps toward an effective demand response program over the past decade. Extensive market reform in the country's energy sector has concentrated increasing control over energy policy with provincial governments. In turn, these government agencies have started pilot LM/DR programs to address rapidly growing electricity demand. These LM/DR programs have realized small but immediate impacts. However, further expansion will require an improved regulatory framework and stable funding mechanisms before a more developed LM/DR portfolio can be achieved. China's current situation most closely resembles that of Saudi Arabia in many ways, with rapidly growing peak demand that is outpacing supply-side additions, frequent brownouts, limited previous experience with LM/DR programs, and a widely deployed TOU rate for large industrial customers.

California

California is at the leading edge of LM/DR efforts not only in the United States, but across the globe. State policy has aggressively promoted LM/DR by prioritizing it, along with energy efficiency and renewables, before all other resources for meeting the state's electricity demand. This strong push from policymakers and regulators has produced a very robust portfolio of LM/DR programs across the state, including traditional reliability-based LM/DR, dynamic pricing, and permanent load shifting.

Much of California's intense regulatory focus on LM/DR stemmed from the California energy crisis of 2000-2001. During this time, due to a number of factors related to the restructuring of the state's energy markets, electricity prices skyrocketed and became extremely volatile, and rolling blackouts occurred across the state. LM/DR was seen as a way to improve the competitiveness of the electricity markets, since gaming of the markets by generators was viewed as one of the major causes of these problems. These benefits, combined with a desire to address rising costs of new generating capacity and a state policy that was opposed to building any new fossil fuel-fired power plants within the state borders, caused the regulators to rethink the approach to meeting the state's electricity needs, and resulted in a renewed interest in LM/DR.

Brazil

Brazil has large hydropower resources, and the availability of multi-year storage reservoirs has generally allowed the country to avoid problems related to capacity shortfalls in the past. However, in 2001 Brazil faced one of the most serious energy crises in the history of its power system. Delays in the construction of new generating capacity, combined with a lack of rainfall to replenish the country's dwindling hydro reserves, made it clear that drastic reductions in demand would be necessary to avoid extended power outages.

In June 2001, the government of Brazil created the Electric Energy Crisis Management Board (known as the GCE) to address the crisis. After considering a load shedding approach where each region would be subjected to power outages on a rotating basis, GCE instead developed a rate program that gave customers a two-tiered price signal. Customers were charged the standard rate for consumption up to a pre-set limit and charged a higher price for usage above the limit. The tariff also established mandatory targets for saving energy that varied by sector. Customer segments had target consumption reductions of 15 to 35 percent energy savings, depending on customer size and sector. Customers that reduced their consumption well below the prescribed quota received bonuses, but those that did not meet the savings targets were subject to service interruption.[13] GCE conducted a large-scale awareness campaign to disseminate information about the power rationing rate and to educate customers about ways to reduce their energy consumption and increase energy efficiency. GCE also established a market where commercial and industrial customers could engage in trading of their savings quota.

The power rationing program achieved extraordinary results. The program resulted in more than a 20 percent reduction in monthly electricity consumption over a nine-month period in 2001 and 2002 that was needed for the crisis to pass, and load shedding and involuntary power outages were never required. A large number of customers exceeded their reduction quotas, and the government was obliged to pay out over $200 million dollars in bonuses.[14] The crisis' impact on the country's GDP was minimized because the savings quota trading market provided an important corrective mechanism to the inherent shortfalls of the quota allocation system.

Australia

Australia's LM/DR activity has grown out of extensive energy market reform that started in the late 1990s. Over the past decade, significant strides have been made in encouraging evaluation of LM/DR programs as cost-effective alternatives to building generation capacity. This has led to extensive pilot programs and trials, the results of which will be useful in adopting broader policies in the years ahead. Although Australia's large coal reserves and profitable export markets are a strong force behind network expansion, regulatory authorities have developed a range of policies which encourage LM/DR in Australia's newly competitive energy markets.

Australia currently has some of the lowest power costs among OECD countries due to extensive large-scale coal operations. Peak demand is mainly caused by summer air conditioning, which has led to a number of pilot projects focused on curtailing load at these end uses. The limited nature of current LM/DR programs can be partially explained by a lack of incentive for retailers, as; however, the incentives for retailers to pursue LM/DR have been limited due to long-term energy contracts that do not expose them to price spikes and short-term price volatility.

South Korea

The Republic of Korea (South Korea) views demand response as an important resource that can help solve capacity shortfall issues. Although not at the leading edge of demand response efforts, the country has gained experience in LM/DR program implementation during the past ten years. Going forward, the country aims to make significant advances in LM/DR technology development (especially Smart Grid) and become one of the global leaders in the field.

South Korea first introduced time-of-use tariffs in the 1970's, and continued to add other load management activities during the 1980's and 1990's. However, the country did not implement programs that fit the definition of modern demand response until the beginning of the past

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13 G. Heffner, L. Maurer, A. Sarkar, and X. Wang. "Minding the Gap: World Bank's Assistance to Power Shortage Mitigation in the Developing World." World Bank. 2009.

14 Venkataraman Krishnaswamy and Gary Stuggins. "Closing the Electricity Supply-Demand Gap." World Bank. 2007.

decade. South Korea's recent history of demand response implementation provides useful information and lessons learned that can be applicable to Saudi Arabia's first efforts in this area.

Italy

Italy, with 30 million smart meters already installed, leads European countries with respect to advanced metering penetration. Additionally, regulators have instituted a mandatory Time of Use rate, which is currently being phased in for all customers. However, with these exceptions, Italy's demand response programs are otherwise still in relatively early stages. The primary demand response programs in the country are traditional interruptible programs and load shedding programs. More innovative demand response programs, such as mass market direct load control and Critical Peak Pricing, are being considered as possibilities for the future.

2.2. Key Insights from the International Case Studies

Each of the six case studies demonstrates varying degrees of success with a diverse mix of approaches to LM/DR. Table 2-2 summarizes the reported impacts of these programs for each country.

Table 2-2: Reported LM/DR Impacts by Country

Country	Predominant source of LM/DR	Known Impacts[1]
China	TOU pricing, interruptible power contracts	10,100 MW reduction (3,000 MW not from involuntary load shedding)
California	Reliability-triggered DR (e.g. interruptible tariffs, DLC)	3,300 MW (6% of peak)
Brazil	Power rationing program	20% reduction in total consumption[2]
Australia	Interruptible power contracts, TOU pricing	350 MW participating in ancillary services market
South Korea	Reliability-triggered DR (e.g. interruptible tariffs, DLC)	2,700 MW (4.5% of peak)[3]
Italy	TOU pricing	10% of peak (expected)[4]

Notes:
(1) These are reported impacts but may exclude impacts of some LM/DR programs
(2) This program was utilized in 2001-2002 but not on an ongoing basis
(3) Excludes impacts of DLC and emergency programs, which were not dispatched
(4) These are expected impacts based on mandatory TOU rollout

From these six case studies, there are a number of important lessons that can be learned which are directly relevant to the current situation in the KSA. Key insights from the case studies are summarized below.

The value of LM/DR in high load factor environments: Program impacts in Beijing demonstrate that LM/DR can provide benefits even in areas with high load factors (in excess of 80 percent). This is a particularly relevant insight for Saudi Arabia, which faces high load factors during the summer season when air-conditioning units are running 24 hours a day.

The importance of basing TOU prices on marginal costs: China's time-of-use (TOU) rate is revenue neutral, but the price differential in the TOU rate varies more significantly than a power supplier's purchase costs. This disparity means on-peak sales are often more profitable to the supplier than off-peak sales, creating a disincentive for suppliers to offer LM/DR programs that would reduce consumption during the peak period. This is an important consideration for the KSA's industrial TOU rate. However, it is equally important not to understate the time-varying nature of the price of electricity, and to reflect all costs in the rate design, to avoid muting the price signal and reducing customer incentive to shift load – provinces of China saw increased enrollment and reductions in peak load as the price differential of the TOU was increased.

<u>Recognizing the importance of the demand-side in market reform:</u> China's electricity market is currently in a state of transition, with the goal of making it more competitive and market-driven. However, this restructuring of the market has not explicitly included measures to address barriers to greater LM/DR adoption, such as decoupling or the inclusion of LM/DR resources in new market rules. As a result, researchers have found that this is limiting greater adoption of LM/DR in the country. By initiating a project on LM/DR, ECRA has already taken steps to ensure the demand-side is recognized during the transition of the KSA's power sector. However, China provides an example that this must be an ongoing concern throughout the transition in order for LM/DR to reach its full potential.

<u>Large reductions require diversified LM/DR program portfolios:</u> China has demonstrated that a few focused LM/DR programs can be valuable tools for quickly addressing critical power supply shortage situations. This can serve as a model for the KSA, which is in a similar situation and exploring opportunities to quickly create a small portfolio of LM/DR options. However, China's experience also demonstrated that a limited approach to LM/DR was not enough to fully address these supply problems, and even with some LM/DR, involuntary curtailments were still needed. A key lesson for the KSA is that it is necessary to carefully select a target amount of LM/DR that will adequately address the country's needs in this area.

<u>Load management standards as an important first step:</u> One of the first steps taken by California in the LM/DR area was to establish four simple and focused load management standards. Many of the programs developed through this effort still exist in some form in the state today. A similar, focused approach could be a key first step for ECRA. As was the case in California, this would give the KSA an opportunity to gain experience with LM/DR and quickly achieve significant impacts. Additionally, some of the factors in California that challenged the success of those early standards do not exist in the KSA today. For example, technological issues that existed in the 1970s have been resolved over that four decade period. The cyclical nature of capacity shortages and surpluses in California is not an immediate concern for the KSA, where there is significant and consistent peak growth. And some of the administrative constraints that existed in California, such as coordination issues between two regulatory bodies plus an independent system operator (ISO), do not exist in the KSA. These are all signs indicating that load management standards could achieve equal or greater success in Saudi Arabia.

<u>Anticipating and managing customer backlash:</u> Recently, California utilities have had to deal with significant customer backlash that has slowed their ability to achieve greater LM/DR impacts. The backlash has focused both on an initiative to require that programmable communicating thermostats (PCTs) be installed in all new homes, and on PG&E's smart metering deployment in Northern California. Both cases arose out of customer misperceptions and are an example of the importance of customer education and public relations. Utilities have severely underestimated the level of customer outreach and education that is needed as

innovative LM/DR programs are rolled out, and the result has been costly. It will be important for the KSA to involve the customer early in this process to avoid the mistakes that have been made by utilities in California and other regions.

A successful aggregator model: California is an example of a region where aggregators can successfully provide LM/DR impacts in the absence of a centralized capacity market. This is similar to the situation in Saudi Arabia, where aggregators would need to rely on SEC to monetize the capacity benefits of LM/DR programs. One key that has made this work in California and has contributed to cooperation between utilities and aggregators, is allowing utilities to count aggregator LM/DR program impacts toward their goals and targets. This applies not only to regulatory or policy targets, but also internally – individual customer reps are allowed to count aggregator impacts toward their internal performance targets, thus aligning incentives and strengthening the relationship between the utility, the aggregator, and the customer.

Aiding the transition to competitive markets: A key motivator for the current level of LM/DR activity in California was a desire to address market issues that had arisen during the state's transition to deregulated and competitive energy markets. As the KSA continues to move forward with its own transition in the energy sector, LM/DR can similarly act as a valuable tool for dealing with related issues and market uncertainty.

Power rationing can complement energy efficiency: The Brazilian power rationing case demonstrated that the decision to adopt a self-rationing system based on quotas rather than involuntary rationing via rolling blackouts can be highly successful. Furthermore, the rationing scheme can complement other energy efficiency strategies, especially when an awareness campaign is conducted to educate customers about ways to reduce their consumption by increasing energy efficiency. The resulting change in customer consumption patterns and behavior can lead to persistence in energy savings well after the end of power rationing.

Significance of centralized approach: The government of Brazil established the Electric Energy Crisis Management Board (GCE) to serve as a temporary entity with special authority to make difficult political decisions. GCE had the highest level of support from the government, and this centralized approach to planning and implementation was required because quick action was imperative during a time of crisis.

Superior solutions require more lead time: Power rationing requires significant lead time to implement, and Brazil had only a few months of hydro reservoir reserve remaining by the time the rationing program was in place. The government of Brazil had almost waited too long to address the impending supply shortage, and the crisis nearly escalated to the point where "last resort" strategies such as load shedding and rolling blackouts become unavoidable. As the KSA considers a variety of options to address rapid load growth and dwindling reserves, this observation has important implications.

Incentivize the organization that will implement the LM/DR program: In Australia, a number of policies are designed to provide financial incentives for retailers to offer LM/DR programs. These programs generally remove the disincentive of lost revenues associated with load reductions, or allow the provider of the LM/DR program to earn a return on the cost savings that the program provides. In the KSA, while the profit motive may not be as strong for SEC and Marafiq as it is for competitive retailers in Australia, this example highlights the importance of ensuring that the utility will have an incentive to pursue any programs that are targeted by national policy. Australia also demonstrates that it can be effective for regulatory policy to encourage LM/DR development, while leaving the methods of implementation up to the utilities.

The importance of pilots: Australia has recently implemented several pilots of various types of LM/DR programs. The successful result of these pilots has established a level of comfort and experience with the programs that is necessary before moving forward with full-scale deployment. As the KSA is still early in the process of gaining experience with LM/DR programs, pilots and demonstration programs will likely be very important for building confidence in the programs.

Customer education is critical: A residential TOU rate that was being rolled out in Victoria has been put on hold indefinitely due to concerns of certain advocacy groups that the rates could disproportionately and adversely affect the poor and the elderly. Research by these advocacy groups suggested that these customers could experience a bill increase of $250 per year. However, other evidence has shown that these customer groups are often immediate beneficiaries on time-based pricing. As in the case of California, this highlights a critical need to educate customers (and consumer groups) about the potential benefits and impacts of time-based pricing or any LM/DR program for that matter. This is a particularly relevant lesson for the KSA, where residential customers currently have very little experience or familiarity with demand-side energy programs and are currently experiencing significantly subsidized electricity rates.

Coordination between program implementers: The South Korean government has allocated funds to the Korea Energy Management Corporation (KEMCO) to implement DSM programs (in addition to providing funds to KEPCO, the utility). Although KEMCO focused mainly on energy efficiency, there were a few programs that overlap with KEPCO's LM/DR activities. The overlap led to an inefficient duplication of efforts, but more importantly, to customer confusion since the two organizations were conducting marketing and public education campaigns that delivered different messages about LM/DR. It will be important for the KSA to coordinate the efforts of all parties involved in LM/DR program implementation in order to avoid duplication of efforts and deliver a consistent message to potential participants.

Determination of LM/DR events: Two of KEPCO's LM/DR programs require that the utility call the curtailment events during a fixed window of time (e.g. July 1 to August 31). Furthermore, KEPCO must announce the events well in advance (one week in advance for the Demand Adjustment Program of Designated Period program, and months in advance for the Demand Adjustment Program of Advance Notice program). While these programs are rooted in the country's load management efforts during the 1980's and 1990's and have been successful in terms of customer participation, announcing the curtailment events weeks or months in advance has sometimes led to events being called on days when there was no capacity shortfall. The KSA should design LM/DR programs with a more flexible method of determining curtailment events to ensure that the resource is dispatched on days when it is needed.

Importance of program monitoring and evaluation: During 2001 to 2008, KEPCO had offered a direct load control program to its customers. However, there has been no reliable data on the customer's response during curtailment events and the program's impacts during the eight years of program operation. It will be important for the KSA to develop reliable and transparent methods of program monitoring and evaluation in order to gauge the progress and ultimately the success of LM/DR programs. This is a topic that will be covered in more detail in the chapters of this report that are related to program implementation.

The impact of strong regulatory influence: The success of Italy's early and strong smart meter rollout is largely due to direction provided by its national energy regulator, the AEEG. The AEEG has also set a strong example by establishing a mandatory TOU rate, particularly in its response to consumer feedback by creating a transition period to help customers adjust to the new peak rate. Further, regulatory influence in this area has included not just mandating program rollouts, but also commissioning new research. The AEEG has commissioned studies on consumer willingness to pay to have remote In Home Displays. Such policies are an example of the significant impact that active regulatory participation can play in the demand-side area.

A phased approach to LM/DR program development: LM/DR implementation in Italy has happened in stages. First, the country developed basic LM/DR programs such as interruptible tariffs. Then, when it identified a need for infrastructure improvements, it pursued a full-scale smart metering deployment with TOU pricing. Most recently, the Centro Elettronico Sperimentale Italiano conducted a study of LM/DR potential in Italy, and found that an additional 2% to 4% of peak demand could be reduced through direct load control of air conditioners and water heaters for residential and small C&I customers, and through critical peak pricing tariffs and demand-side bidding for large industrial customers. These programs are being considered for future development. A similarly staged approach in the KSA, identifying short-, medium-, and long-term LM/DR opportunities, could be a beneficial pragmatic approach to rolling out new programs.

Environmental benefits of LM/DR in region with less diverse supply mix: There is some controversy surrounding the environmental impact of LM/DR. In regions where gas is on the margin during peak hours and coal is on the margin during off-peak hours, load shifting could potentially lead to an increase in emissions. However, in Italy, where the supply mix is less diversified, the fuel source is typically the same for plants on the margin in both periods, but the efficiency of the marginal plants during the peak is worse. This is what has led to the significant potential environmental benefits reported for Italy's TOU program. The KSA is in a similar situation, with higher emissions units running during peak times, and lower emissions units running during off-peak times. It is likely that similar environmental benefits could be realized from permanent load shifting in Saudi Arabia.

SIDEBAR: ENERGY EFFICIENCY POLICY IN OTHER COUNTRIES

In addition to LM/DR, energy efficiency (EE) is potentially a valuable option for reducing the KSA's rapidly growing peak demand. Recently, the Japan International Cooperation Agency (JICA) conducted a study for the KSA which included a detailed survey of energy efficiency policies and programs being implemented around the globe.[15] Countries that were covered in this survey included Japan, the United States, the United Kingdom, Germany, Australia, Thailand, and Indonesia. A synthesis of the common characteristics of energy efficiency policy in these case studies provides some helpful insights for how ECRA may wish to pursue its demand-side management efforts. The following are key observations from this survey that are relevant to important aspects of our project.

Targets: Each of the surveyed countries has one or several targets related to energy efficiency. These targets can be tied to various metrics, such as carbon dioxide emissions, energy consumption per GDP, or gasoline usage. The nature of these metrics defines the overall objective of the energy efficiency policy in each country. In the KSA, the importance of a carefully selected and well-defined target will apply not only to energy efficiency, but to LM/DR as well. A target should be complemented with key performance indicators that are used to measure the performance of the policy.

Labeling and efficiency standards: Nearly all of the surveyed countries had at least some form of labeling and efficiency standards. However, there were significant differences across countries, in terms of how aggressive the standards are, which appliances or sectors the standards apply to, and whether the requirements are mandatory or voluntary. For example, in Australia, one of the first countries to adopt a labeling requirement, mandatory minimum efficiency levels have been established for refrigeration, lighting, air-conditioning, and other end-uses. Indonesia, on the other hand, does not have an efficiency standard but several are under consideration. The KSA is in the early stages of its own labeling program, with a low efficiency requirement on air-conditioners. A key next step in this area will be enforcement of these and any new standards that are developed.

Programs: The surveyed countries offer a wide range of energy efficiency measures including, for example, energy audits, awareness campaigns, street lighting programs, and CFL rebates. Each of these programs is typically implemented by the utility and subject to the cost-effectiveness analysis that is part of the utility's long-term planning process.

Policy level (national versus local): In some countries, energy efficiency efforts are driven primarily by national policy, and in other countries the driver comes more from local policy. For example, in the United States, there are strong efficiency standards for many appliances, but much of California's success with energy efficiency (per-capita energy consumption has remained constant since the 1970s) has been driven by standards and programs at the state level. Alternatively, in Japan, energy efficiency is a critical component of national energy policy, and activity in this area is driven by a series of well-defined national energy plans. Given the size and organization of the KSA, it is likely that a national policy will need to be the key driver of demand-side activity.

[15] For details on all of these case studies, see Chapter 2 of *The Master Plan Study for Energy Conservation in the Power Sector in the Kingdom of Saudi Arabia, Draft Final Report*, prepared by JICA, July 2008.

3. THE CURRENT DSM LANDSCAPE IN THE KSA

The current DSM institutional landscape in Saudi Arabia consists of a number of policy-making entities and one primary implementation entity. With respect to the programs being offered, there is a limited but growing portfolio of DSM programs that are reporting to have achieved significant levels of impact on the Saudi power system.

In 2001, it was estimated that peak load savings of more than 871 MW were realized in Saudi Arabia as a result of sustainable energy policies and strategies implemented in the Kingdom.[16] While these activities included LM/DR measures, the majority of the peak load savings measured in 2001 were primarily through EE and energy conservation measures (described in more detail below). Today, SEC estimates the current impact from its LM/DR activities, excluding EE and conservation measures, is approximately 1,000 MW.[17] To our knowledge, no other formal measurement of total DSM impacts currently exists within the Kingdom.

This chapter outlines both the institutional landscape and the key DSM measures currently deployed in Saudi Arabia.

3.1. INSTITUTIONAL LANDSCAPE

There are several different organizational entities within the KSA providing overall supporting frameworks for DSM strategies, policies and regulations. The Ministry of Water and Electricity (MOWE), the Electricity and Co-generation Regulatory Authority (ECRA), the Saudi Electricity Company (SEC), the Saudi Arabian Standards Organization (SASO) and the Saudi Energy Efficiency Center (SEEC) are the primary institutions currently helping to shape the overall DSM landscape within Saudi Arabia.

Each entity takes part in various policy-making aspects and provides overall strategies, direction and regulations related to DSM in varying degrees. From a deployment perspective, SEC is the only entity responsible for the development and implementation of all LM/DR measures currently in the KSA. In contrast, the development and implementation of EE measures are currently led by a combination of several different institutions. Table 3-1 outlines the primary institutions and their key responsibilities as it relates to DSM within the KSA.

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16 "Developing sustainable energy policies for electrical energy conservation in Saudi Arabia", S.A. Al-Ajlana, A.M. Al-Ibrahim, M. Abdulkhaleq, F. Alghamdi, 12 Jan 2005

17 SEC Load Management Team Interview, 15 Dec 2010

Table 3-1: Primary Institutional Involvement for DSM in Saudi Arabia

Entity	Primary DSM Involvement[18]
Ministry of Water and Electricity (MOWE)	• Lead overall energy conservation and efficiency strategies and policies • Prepare, endorse and follow-up on the execution of programs • Develop and implement a public awareness plan
Electricity and Co-generation Regulatory Authority (ECRA)	• Provide supportive regulatory framework and tariffs/ incentives for DSM activities • Adopt a long term plan that include increasing DSM activities
Saudi Electricity Company (SEC) / Marafiq	• Implement LM/DR programs and measures within the KSA • Support research in EE technology • Collaborate in implementing efficiency awareness
Saudi Arabian Standards Organization (SASO)	• Develop household appliance/ equipment efficiency standards and labeling program • Develop building codes and standards • Promote standards awareness
Saudi Energy Efficiency Center (SEEC)	• New, permanent entity converted from the former National Energy Efficiency Program (NEEP) • Develop, implement, monitor and coordinate all EE efforts

While SEC is responsible for developing and implementing LM/DR programs, currently SEC does not have any specific peak load reduction targets or savings to achieve from these activities. Under Ministerial Decrees 169 and 170, SEC is required to direct funds to support research at universities, institutes and energy conservation centers related to DSM. However, SEC is not obligated to implement any DSM program or measure within the KSA. The issue of DSM implementation challenges and potential solutions will be discussed later in this report.

SEC, in cooperation with MOWE, also supports the implementation of EE measures, specifically EE awareness programs. However, the majority of EE implementation in the KSA is led by individual electricity consumers, specifically the largest industrial customers, ARAMCO and SABIC. This is further outlined in Section 3.3 in this report.

The Saudi Energy Efficiency Center (SEEC) was formally organized in 2010. SEEC is the new, permanent organizational entity continuing the efforts of the National Energy Efficiency Program (NEEP). NEEP, a UNDP-sponsored program established within the Energy Research Institute of King Abdul Aziz City for Science and Technology (KACST), concluded its program of objectives in 2007/8. It is envisioned that SEEC will eventually lead all development, implementation, monitoring and coordination efforts related to all EE activities in the KSA. However, SEEC's formal operating charter is still under development and its organizational capacity and capability is currently being developed.

[18] Team Interviews 15 Dec 2010 and 10-12 Jan 2011; Review of Electricity Law. Royal Decree No. M/56, 20 Shawwal 1426/22 November 2005

3.2. Summary of LM/DR Activities

The LM/DR measures currently deployed have all been developed and implemented by SEC, many with support from academic institutions within KSA and third-party consultants.[19] Currently, there are five LM/DR measures deployed in Saudi Arabia:

- Time of Use (TOU) Rates
- Thermal Energy Storage (TES) Promotion
- Large Air-Conditioning Direct Load Control (A/C DLC)
- Standby Generation[20]
- Voluntary Load Curtailment

While we do not have the data to quantify the specific impact of each of these measures in Saudi Arabia, SEC has estimated that peak load savings of 1,000 MW have been, over half of which are a result of the SEC's voluntary TOU rate program.

3.2.1. TOU Rates

In 2006, SEC implemented a voluntary TOU rate program for its largest commercial and industrial (C&I) customers. In 2010, ECRA approved the implementation of mandatory TOU for the Industrial customer segment.[21] While TOU rates are now mandated for industrial customers with digital meters, the voluntary TOU program is still available for large commercial customers.

Table 3-2 describes SEC's voluntary TOU rates and Table 3-3 describes the new mandatory TOU rates for industrial customers.

SEC's voluntary program was directed at both commercial and industrial customers with energy consumption greater than 600 MWh per year and loads greater than 1 MVA. The voluntary TOU rate structure was designed to encourage peak load shifting during the summer months of June, July, August and September with a peak to off-peak ratio of over 4 to 1.

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[19] CRA International conducted a comprehensive DSM and Rate Design Project in 2005 which, for example, formed the basis for the TOU rate program by SEC

[20] Standby generation does not fall into the definition of LM/DR programs for the purposes of new measures being introduced for this project, as it is considered to be another form of generation, but it is included here for completeness.

[21] ECRA Board of Directors Decision (1/22/31) dated 01/06/1431 AH

Table 3-2: Voluntary TOU Rates for Commercial & Industrial Customers

Months	Hours	TOU Tariff (hh/kWh) *(Consumption >600MWh/yr and Load >1MVA)*	
		Commercial	**Industrial**
October – May	All	**26**	**12**
June – September	<u>Off Peak Hours</u> Saturday to Wednesday: 5pm – 12pm (19 hours) Thursday to Friday: All hours	**17**	**8**
	<u>Peak Hours</u> Saturday to Wednesday: 12pm - 5pm (5 hours)	**76**	**35**

Source: SEC

Table 3-3: New Mandatory TOU Rates for Industrial Customers

Months	Hours	TOU Tariff (hh/kWh) *Customers with Digital Meters*	
		Small Industrials (Less than 1MVA)	**Large Industrials (Greater than 1MVA)**
October – April	All	**12**	**14**
May – September	<u>Off Peak Hours</u> Saturday to Thursday: 12am - 8am (8 hours) Friday: 12am - 9am 9pm -12am (12 hours)	**10**	**10**
	<u>Peak Hours</u> Saturday to Thursday: 12pm - 5pm (5 hours)	**26**	**26**
	All Other Hours	**15**	**15**

Source: ECRA

By 2010, 1,135 customers were on the voluntary TOU rate program. SEC estimated the total amount of peak load shifted during the summer months was 565 MW, or approximately 500 kW per TOU customer. Table 3-4 summaries the voluntary TOU program results by year.

Table 3-4: Voluntary TOU Program Results

TOU Program	2006	2007	2008	2009	2010
By Operating Area	Central	Central East West	Central East West	Central East West	Central East West South
Commercial Customers	11	37	72	191	219
Industrial Customers	34	145	296	721	916
Total Number of Customers	45	182	368	912	1,135
Shifted Load (MW)	**21.5**	**90.6**	**196.0**	**412.5**	**565.0**

Source: SEC

From the data provided by SEC, it is difficult to draw any definitive conclusions about the specific savings impact from a full-scale program. The results do highlight that the TOU rates were able to induce some load shifting by SEC's large customers. However, the actual percentage of the customers' load that was shifted during these peak times is unknown.

The results of the voluntary program did lead to a full-scale roll-out of TOU rates in Saudi Arabia. In 2010, ECRA, in cooperation with MOWE and SEC, approved the mandatory TOU rate program for the industrial segment.

All industrial customers with digital meters will be enrolled in the new TOU rate program starting the summer of 2011. The industrial TOU rate structure has been designed to encourage peak load shifting during the summer months of May through September with a peak to off-peak ratio of less than 3 to 1. Customers without digital meters will be enrolled in a seasonal rate program of 12 hh/kWh during the winter months of October through April and 15 hh/kWh during the summer months of May through September.

3.2.2. TES Promotion

SEC promotes the use of thermal energy storage (TES) systems to its large commercial customers. SEC distributes information regarding various TES systems and discusses its benefits to potential customers within the KSA. In addition, SEC works with manufacturers and importers of TES equipment to communicate and encourage adaption of the technology. However, beyond the voluntary TOU rate program, there are no other incentives to encourage customers to install TES systems at their facilities.

Despite the lack of customer incentives to encourage the installation and use of TES, there are approximately 10 TES customers in the KSA. In fact, all of these systems were installed prior to 2006, before any TOU rate was offered.

SEC estimates peak load shifting capacity from these installations is approximately 20 MW. Table 3-5 is a summary of the current TES customer applications in Saudi Arabia, which are all currently believed to be active.

Table 3-5: TES Customers in Saudi Arabia

Customer (Building Name)	Operating Hours		Number of Chillers	Chiller Capacity (1000BTU)	TES Capacity (1000 BTU/HR)
	From	To			
SABIC HQ Building	6 pm	6 am	6	26,400	232,320
Al-Tameer center	11 pm	6 am	7	21,600	212,400
Qrnata commercial center	11 pm	6 am	7	4,800	200,640
Faisaliah	8 pm	8 am	3	16,560	198,720
NCCI	10 pm	7 am	8	24,960	179,712
Samba	7 pm	5 am	4	15,360	115,200
Saudi French Bank	6 pm	6 am	2	1,020	110,880
Kingdom tower	10 pm	8 am	4	12.600	100,800
King Abdulaziz Museum	10 pm	8 am	2	8,400	84,000
Riyadh Main Court	8 pm	6 am	3	9,600	67,950

Source: SEC

3.2.3. Large A/C DLC

In 1996, SEC began a voluntary remote load control program of large air conditioning units for the government and commercial customers in SEC's Central Operating Area (COA). Today, there are approximately 43 sites (39 government and four commercial customers) participating in this large A/C DLC program with a total controllable load of 90 MW. This specific A/C DLC program in COA has not been expanded across SEC. The West Operating Area (WOA) has implemented a similar A/C DLC program in the past; however program details are not available.

During periods of peak load, SEC can remotely control 90 MW of capacity in the COA through the use of different paging and SMS technologies. The compressors of the air-conditioning systems are cycled on and off for set periods of time, thus reducing peak loads. According to SEC, the last operation of the COA A/C DLC system was in 2009. Approximately 35 MW of system peak load was reduced at that time.[22]

3.2.4. Standby Generation

The standby generation program is another voluntary program targeting SEC's large commercial, industrial and government customers. The installed standby generating capacity at each

[22] SEC Load Management Team Interview, 12 Jan 2011

customer location varies from 0.5 MW to 30 MW in size.[23] SEC conducts negotiations with large consumers that have installed their own standby generation and asks them to use their own generation capacity for emergency and system reliability purposes during peak times. Notification letters are sent at least one week ahead of time and phone calls are made in critical situations.

These voluntary, bi-lateral agreements are based solely on an honor system. Furthermore, there are no incentives or compensation provided by SEC for the use of these standby generators. Even fuel and other operating costs are currently borne by the individual customers operating their standby generators.

The standby generation program has been in use for a number of years. However, the last known use of the standby generation program in the KSA is unknown. In addition, to our knowledge, there are no specific measured peak load impacts for this program.

3.2.5. Voluntary Load Curtailment

The Voluntary Load Curtailment program targets SEC's largest industrial customers in the Kingdom. During critical peak load periods, SEC system control asks large industrial users to voluntarily reduce their electric usage. Many of Saudi Arabia's largest industries have helped SEC avoid the need for more drastic system load curtailment measures, such as rolling blackouts and power cuts, by using the customers' own emergency generators, reducing electric use and/or shutting down operations when possible. As with the standby generation program, notification letters are sent at least one week ahead of time and phone calls are made in critical situations. There are no financial incentives provided to customers for participation in the program. The only customer incentive to actively participate is to avoid a full-scale blackout that would dramatically affect their operations.

From SEC's perspective, the use of the program during peak periods has been very successful over the years. However, the potential economic cost to industrial customers, and the Kingdom as a whole, from limiting industrial output is unknown, and potentially very large.

3.3. Summary of EE Activities

<u>*Awareness Building*</u>

An Energy Conservation and Awareness Department was created within MOWE to develop and implement a comprehensive energy conservation plan. To date, its focus has been building awareness of energy conservation among energy users and the general public and working with SEC to actually implement energy conservation and load management programs.

These programs have encouraged large consumers to reduce and shift peak loads, regulated agricultural irrigation during peak load times, disseminated the *Energy Conservation and Load Management Consumers' Guide*, and promoted energy awareness through various workshops,

[23] SEC Load Management Team Interview, 12 Jan 2011

meetings, and site visits with end users.[24] In addition, an outreach program has been implemented that targets secondary/ high schools and colleges and teaches students about general energy conservation and efficiency.

EE Standards, Codes & Labeling

SASO is very active in the area of appliance efficiency standards, building codes and appliance labeling for EE. In 2003, SASO adopted voluntary standards to encourage import of efficient electrical appliances.[25] SASO, in collaboration with NEEP, also developed an energy building code suitable for the Kingdom's climate and cultural requirements.

Recently, SASO developed a labeling program, which assigns between one and five stars to all new air-conditioning units sold in the Kingdom depending on their level of energy efficiency. This is currently only an informational program, but it is a first step in a move toward establishing a minimum standard that must be satisfied for new air-conditioning units. While SASO has established these energy standards, building codes and labeling programs, there is no enforcement mechanism within the Kingdom to ensure any standard or code is actually followed or implemented.

EE for Large Industrials

Energy conservation and efficiency efforts at the largest industrials in Saudi Arabia, namely ARAMCO and SABIC, have been underway for years. Both ARAMCO and SABIC maintain their own standards for energy efficiency and energy safety requirements. In addition, each company routinely invests in energy efficiency programs and measures within their organizations to improve operating costs.[26] In fact, ARAMCO has been pursuing an EE program intended to reduce their US$500 million annual energy bill by half by 2012.[27]

Each of these large industrial companies also has the internal organizational capacity for EE and general energy management through various EE Departments, Power Distribution Departments, Inspections Department, Engineering Support Department and Conservation Departments.[28] Most all of these departments implement ongoing internal energy awareness campaigns, conduct energy audits and implement various internal EE measures.

Although significant progress in industrial EE has been made, these results and the technical capacity, for energy auditing and improvement have not spread beyond large industrials in the Kingdom. SEEC, continuing on the initial energy auditing work conducted by NEEP, plans to build this EE capability in Saudi Arabia.[29] One of SEEC objectives will be to expand the concepts of energy audits, energy efficiency and conservation throughout all consumer segments.

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24 NEEP Final Report, Energy Efficiency Information and Awareness, Volume 2A, Sections 3 and 4, March 2008
25 Kingdom of Saudi Arabia National Energy Conservation Strategy, The World Bank, 15 April 2007
26 NEEP Final Report, Energy Audit Services and Industry Support, Volume 1A, Sections 3 and 4, March 2008
27 Kingdom of Saudi Arabia National Energy Conservation Strategy, The World Bank, 15 April 2007
28 ARAMCO, SABIC Interviews, 12-13 Dec 2010
29 Kingdom of Saudi Arabia National Energy Conservation Strategy, The World Bank, 15 April 2007

However, this organizational capacity within SEEC to help spread the benefits of EE across the Kingdom is still under development.[30]

3.4. POSSIBLE MODIFICATIONS TO EXISTING MEASURES

As discussed, the current portfolio of DSM measures in the Kingdom has resulted in potentially significant peak load benefits. We do not have the information required to validate SEC's estimate, however the peak load savings from the current DSM measures may be approaching 1 GW.[31] Despite these impacts, there are a number of ways in which the existing measures can be modified or expanded in order to increase their overall effectiveness. These potential program modifications are described in Table 3-6.

Most notably, SEC is not currently recognizing the potential impacts of its 1,000 MW LM/DR portfolio into its long-term resource planning process. Therefore, the benefits of these measures, as currently deployed, are most likely limited to location-specific reliability value. By consistently utilizing the programs to reduce the overall system peak, and measuring and validating their impacts, the full potential for avoided supply-side resource costs could be realized.

The overall objective of this project is to outline a comprehensive strategy for implementing DSM programs within Saudi Arabia. Through the project, we will identify the most attractive programs to offer in the KSA and outline steps for their successful deployment. As a complement to these recommendations, the potential methods for enhancing existing programs that we have outlined here can have significant positive impact from the current DSM measures in Saudi Arabia.

[30] Dr. Naif M. Al-Abbadi, SEEC Director General, Interview, 10 Jan 2011
[31] SEC Load Management Team Interview, 15 Dec 2010

Table 3-6: Possible Areas for Modification in Current DSM Programs

Current KSA Measures	Methods for Increasing Impact & Effectiveness
LM/DR Measures	
TOU Rates	• Expand TOU rate program to all customer segments (voluntary or mandatory)[32] • Deploy a higher peak to off-peak pricing ratio
TES Promotion	• Provide customer incentives/ rebates for the required equipment (if the program is deemed cost-effective) • Explore opportunities to promote retrofit applications of TES
Large A/C DLC	• Provide customer incentives to expand participation • Expand program across KSA to commercial, government (such as schools, mosques and hospitals) and large residential customers
Standby Generation	• Provide customers incentives to expand participation • Reimburse customers for some or all of the fuel and operating costs
Voluntary Load Curtailment	• Provide customer incentives to participate in order to expand participation; consider a tiered incentive structure that offers higher payments for mandatory ("firm") load curtailments
EE Measures	
Awareness Building	• Create broader mass media campaigns • Implement social/behavioral-type awareness, focusing on individual consumers
EE Standards, Codes & Labels	• Enforce standards and codes • Develop minimum standards for A/C efficiency (e.g., minimum star ratings)
EE for Large Industrials	• Create Energy Service Company (ESCO) industry to lead additional EE implementation • Expand EE technical capabilities across KSA, leveraging Large Industrial experiences

3.5. Smart Meter Deployment

Currently, there is a major smart meter deployment program underway within the KSA for all Industrial customers. The implementation of the new TOU rate for Industrial customers requires the installation of a digital meter to record electricity use by time of day. The deployment of smart meters for this customer class is a first step in a major automated metering infrastructure

[32] Assumes smart meters/AMI is in place

(AMI) across the Kingdom. Both SEC and Marafiq have plans in place to deploy smart meters across this key customer segment.

In addition, SEC is currently in the early stages of a pilot program to install approximately 60,000 smart meters across all customer segments in the KSA. This large-scale pilot deployment at SEC is primarily geared towards testing their selected metering and infrastructure technology. The extreme weather conditions in the KSA are a significant challenge for the deployment of conventional digital technology. One of the key objectives is to prove the technology use case of the meters within the KSA, and serve as a model for potential deployment across the entire KSA.

Smart meter/AMI technology is a critical first step in enabling many additional DSM measures in the KSA in the future. It enables access to pricing information that more accurately reflects actual market conditions and gives customers greater control over their energy use and bills. In addition, AMI deployments across the world have been proven to also enable new home automation/information systems, auto-demand response for commercial buildings and industrial factories and new electricity storage technologies.

4. THE BASELINE ANALYSIS

The baseline analysis represents the foundation for our assessment of the DSM measures. It provides a marker against which changes to customer demand brought about through DSM measures and programs can be measured. Results of the baseline analysis are calibrated relative to actual historical data on energy use, peak demand and other indicators such as per-capita energy consumption, number of electricity customers, and electricity intensity. All potential savings resulting from the DSM measures are derived from the baseline.

According to the National Energy Efficiency Program (NEEP), the major sectors that consume the most electricity in the KSA are residential and industrial.[33] Within the residential sector, most of the electricity usage is estimated to come from single-family homes and apartments.[34] Within the industrial sector, most of the electricity usage is estimated to come from the chemicals and plastic products industries and metal products, machines and equipment industries.[35]

The baseline analysis is comprised of the following four elements:

- Reference condition: The reference condition classifies the actual peak demands, energy consumption and number of electric end-use customers segmented according to various definitions of region, market segment, customer size and end-use equipment.
- Baseline forecast: The baseline forecast reflects how the "Reference Condition" will be represented into the future. It serves as the starting point from which to project all future impacts associated with DSM initiatives.
- Avoided costs: The avoided costs provide the basis by which the benefits of the DSM measures can be quantified. They represent the costs of the supply-side resources that would need to be put into place as a result of the various DSM programs.
- System and segment load shapes: The system and segment load shapes help to clarify when loads on the electrical system reach their highest levels during the day and further define the market segments that potentially contribute most to those load conditions.

Each element is addressed in the sections that follow.

4.1. REFERENCE CONDITION

Based on our extensive review of the various documents provided by ECRA, we have determined that the reference condition should be split into the following segments:

- By four regions (Eastern, Central, Western, Southern)
- By five market segments (Residential, Commercial, Government, Industrial, Other)
- By three customer size categories as defined by energy use (Small, Medium and Large)
- By end-use equipment (Cooling, Lighting, Refrigeration, Appliances, Motors, etc.)

33 NEEP, Energy Efficiency Information and Awareness, NEEP Objective [2], Final Report, October 2007.
34 *Ibid.*, p. 116. Conclusion based on insights derived from Table 6.
35 *Ibid.*, p. 118. Conclusion based on insights derived from Table 8.

The reference year selected for the analysis is 2011. This year was selected because it serves as the starting point for the projected DSM potential impacts and subsequent programs and initiatives. Three major indicators are developed for the reference condition in 2011: peak demand, energy use and number of customers.

4.1.1. Peak Demand

According to data provided by ECRA, the total peak demand for KSA in 2011 is expected to be 46.5 GW.[36] Figure 4-1 illustrates how the peak demand is segmented by region and sector. Note that this figure reports the estimated system coincident peak demand for 2011.

The peak demand estimates were derived using a combination of electricity sales and load factors. Electricity sales numbers for the four regions were obtained from a 2010 report provided by ECRA.[37] Sectoral shares in the total energy consumption by region were calculated using data obtained from a 2007 report to the Ministry of Water and Electricity (MOWE).[38] These shares were applied to the regional electricity sales numbers in order to derive electricity sales forecasts by region and by sector. The 2007 report also provided average load factors by sector for residential, commercial, government, industrial, and agricultural customers.[39] These load factor values were applied to the sectoral electricity sales to derive sectoral peak demand values.
Later in this chapter, we describe how that peak is distributed across the hours of the day and across the various end-use customer sectors.

36 '*Volume I- Revised Generation Planning Report- Electricity Generation and Transmission Plan (EGTP)*'; Prepared for Ministry of Water & Electricity (MOWE), Riyadh, Saudi Arabia; January 2010

37 *Ibid.*

38 *'Development of Electricity Generation and Transmission Plan for Saudi Arabia - Electricity Demand Forecast'*; June 2007.

39 *Ibid.* The report indicates the following load factors by sector- Residential: 50%; Commercial: 63%; Industrial: 80%; Governmental: 65%; Agricultural: 60%;

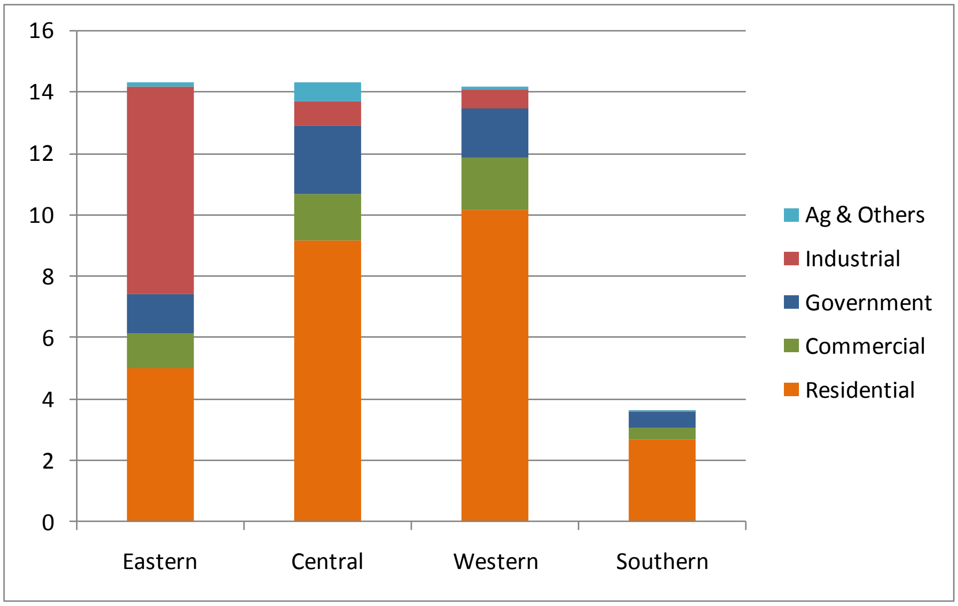

Figure 4-1: 2011 Peak Demand (Gigawatts or GW) by Region and Sector

The following findings and observations are made from the figure:

- The Central, Eastern, and Western regions have equal shares in the overall peak demand. In the Eastern region, most of the peak load comes from the industrial sector (nearly half). In the Central and Western regions, over two-thirds of the load comes from the residential sector.
- The Southern region contributes less than 10% to the overall peak demand, with the vast majority coming from residential.
- For the KSA as a whole, the residential sector dominates in the overall system peak, with close to 60% share. It is estimated that cooling makes up a vast majority of the residential peak load.
- The Industrial share of total peak demand in the KSA is close to 20%.
- Government and Commercial have similar contributions to peak demand at 10% each.

4.1.2. Energy Use

According to data provided by ECRA, the energy use for the KSA in 2011 is expected to be 231,260 GWh.[40] To gain a more complete understanding of how this energy was consumed, we segmented this total in a variety of ways. First, we divided the energy use by KSA region and sector. As described earlier under Section 4.1.1, we applied sectoral shares to the total electricity consumption forecast numbers by region, using data from reports obtained from ECRA.[41]

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[40] '*Volume I- Revised Generation Planning Report- Electricity Generation and Transmission Plan (EGTP)*'; Prepared for Ministry of Water & Electricity (MOWE), Riyadh, Saudi Arabia; January 2010.

[41] As indicated earlier, the report titled '*Volume I- Revised Generation Planning Report- Electricity Generation and Transmission Plan (EGTP)*'; Prepared for Ministry of Water & Electricity (MOWE), Riyadh, Saudi Arabia; January 2010' provided regional sales forecast. Sectoral shares in energy use by region was derived using data presented in the report titled- *'Development of Electricity Generation and Transmission Plan for Saudi Arabia -*

Figure 4-2 illustrates how the energy use is segmented by region and sector. The following findings and observations are made from the figure:

- As with the peak demand, the Central, Eastern, and Western regions have equal shares in the overall energy consumption.
- Overall, the residential sector contributes to over half of the electricity usage (51%), with industrial at 22%, government at 14% and commercial at 11%. The other category includes such segments as agriculture, streets, mosques, and charity organizations.

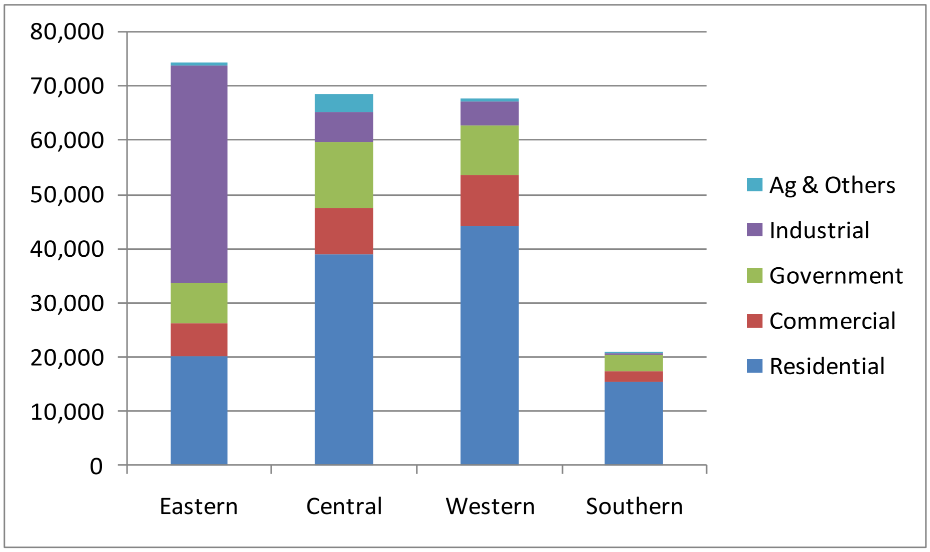

Figure 4-2: 2011 Energy Use (Gigawatt-hours or GWh) by Region and Sector

Figure 4-3 shows how the 2011 energy use is distributed by sector for each of the four regions. Much like peak demand, the sectoral share in total energy consumption varies significantly across regions. Residential customers dominate energy use in the Central, Western and Southern regions while industrial customers (mostly chemicals) dominate the energy use in the Eastern region.

Electricity Demand Forecast; June 2007.' These shares were then applied to the regional sales forecast to come up with sectoral sales forecast for the four regions.

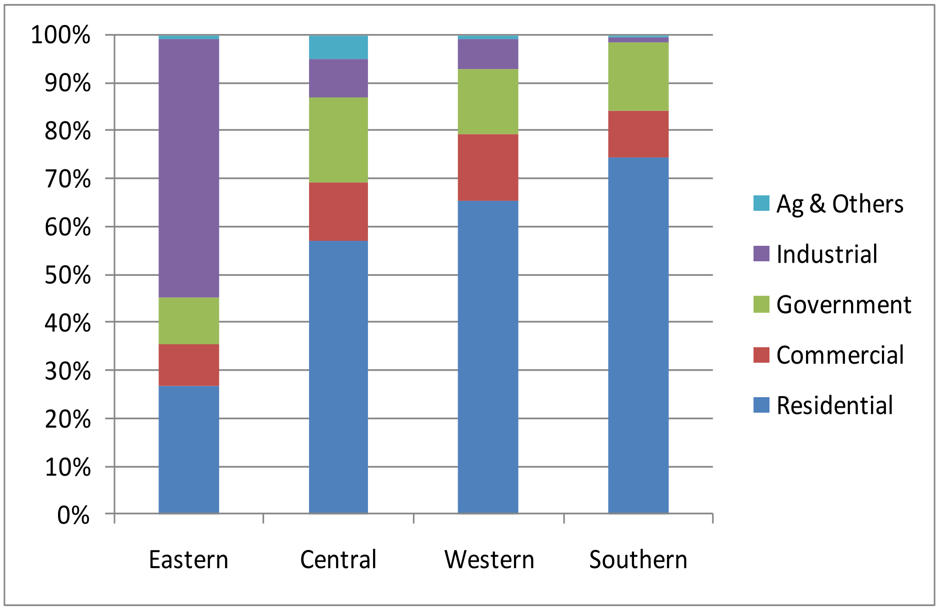

Figure 4-3: Sectoral Share in 2011 Electricity Use by Region

We also examined energy use by end-use. Figure 4-4 provides a breakdown of the estimated 2011 energy use by end-use for the residential sector. These figures were derived using end-use shares extracted from the NEEP study.[42] As can be seen in the chart, cooling has a very high share in overall residential energy use, at greater than 70%. This is no surprise given the amount of cooling required for residents to withstand the long hot summers in the KSA. Furthermore, based on anecdotal evidence that we collected during our various in-country meetings, the efficiencies of most residential air conditioning systems tend to be relatively low, leading to greater amounts of energy consumption than might otherwise be the case.

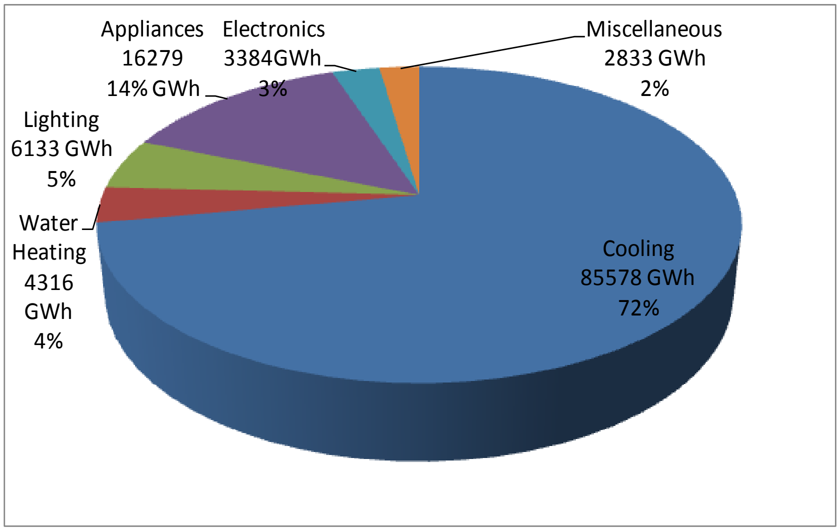

Figure 4-4: 2011 Residential Energy Consumption by End-Use

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42 National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A, Table 38 (Page 164).

The type of cooling equipment in the residential sector varies depending on the building type and the demographic characteristics of the resident. Typically, central air conditioning systems are found in very large single family homes. Window air conditioning systems are typically found in apartment buildings. Split system air conditioning systems are common in most other types of residential building types in the KSA including small and medium-sized single family homes, villas and flats. Figure 4-4 indicates that appliances such as refrigerators, clothes washers, electric dryers, dishwashers, and cooking equipment are estimated to have the next highest share at 15%. The remaining end-uses each have a 5% (or less) share in the total energy consumption. These end-uses include lighting, water heating, home electronics (including computers and televisions), and miscellaneous which may include vacuum cleaners, hair dryers, microwave ovens, irons, etc.

Figure 4-5 provides a breakdown of the estimated 2011 energy use by end-use for the commercial sector. Because of a lack of primary data indicating energy usage by end-use in the commercial sector, we derived these figures drawing on relevant secondary sources with appropriate adjustments to reflect conditions as we know them for KSA.[43] The HVAC end-use, which is comprised primarily of cooling systems (central chillers, packaged rooftop units, and split-system A/C) and ventilation pumps and motors make up more than half of the total commercial energy use. Lighting systems include fluorescent lamps and fixtures, incandescent lamps and high intensity discharge lighting for high bay applications and outdoor lighting.

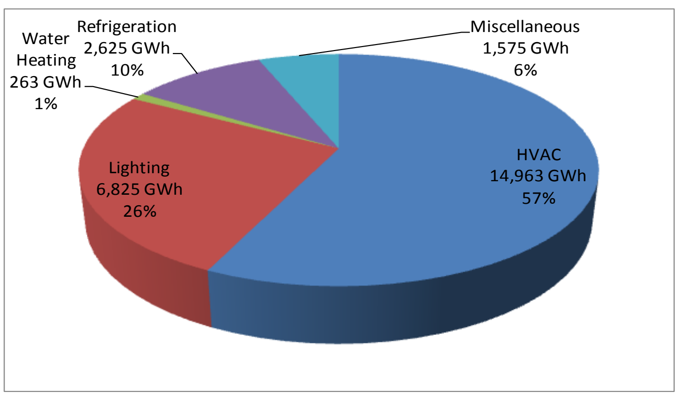

Figure 4-5: 2011 Commercial Energy Consumption by End-Use

Figure 4-6 provides a breakdown of the end-use energy consumption for the government sector. These shares were derived drawing from the same secondary sources used for the commercial sector.[44] Similar to the commercial sector, half of the energy use in government buildings is for HVAC systems, primarily the same types of systems that are present in the commercial sector. It is worth noting that HVAC use is estimated to be slightly lower in government buildings relative

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[43] The shares were derived using a combination of data obtained from the following sources- 'National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A'; 'Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to meet Texas's Growing Electricity Needs; American Council for Energy Efficient Economy; March 2007'; 'Electric Power Research Institute (EPRI), Assessment of Achievable Potential from Energy Efficiency and Demand Response, 2009. Each of these sources were used to derive the commercial end-use shares that are, in our judgment, most reflective of the commercial conditions prevalent in the KSA.

[44] *Ibid.*

to commercial buildings. This may be due to the fact that there is a broader mix of building types and end-uses in the government sector than would be typically found in the commercial sector.

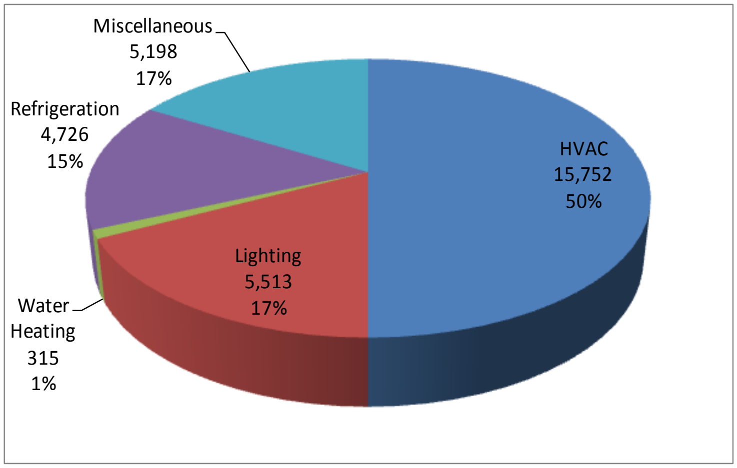


Figure 4-6: 2011 Government Energy Consumption by End-Use

Refrigeration and lighting have an almost equal contribution, ranging between 15 and 20%. In addition to building lighting systems, lighting also includes municipal streetlights. The remaining is accounted for by water heating and miscellaneous. In the miscellaneous category, it is estimated that municipal water pumping and sewage treatment make up a large share of the total usage for this category.

Figure 4-7 provides a breakdown of the end-use energy consumption for the industrial sector. Again, due to the limited amount of primary data at the end-use level, the end-use shares were derived using the best available secondary data.[45] Electricity use by motors dominates industrial energy use with a 70% share. Compressed air systems make up another 20%. These findings are typically common for most industrialized countries including the US, Europe, Korea and Japan. Unlike the commercial sector, HVAC shares are only 5% of the total use while lighting makes up another 2%. Miscellaneous use rounds out the total with 3%.

[45] Data sources for the industrial sector were generally derived from a combination of data obtained from the following sources- 'National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A'; 'Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to meet Texas's Growing Electricity Needs; American Council for Energy Efficient Economy; March 2007'; 'Electric Power Research Institute (EPRI), Assessment of Achievable Potential from Energy Efficiency and Demand Response, 2009. Each of these sources were used to derive the industrial end-use shares that are, in our judgment, most reflective of the industrial conditions prevalent in the KSA.

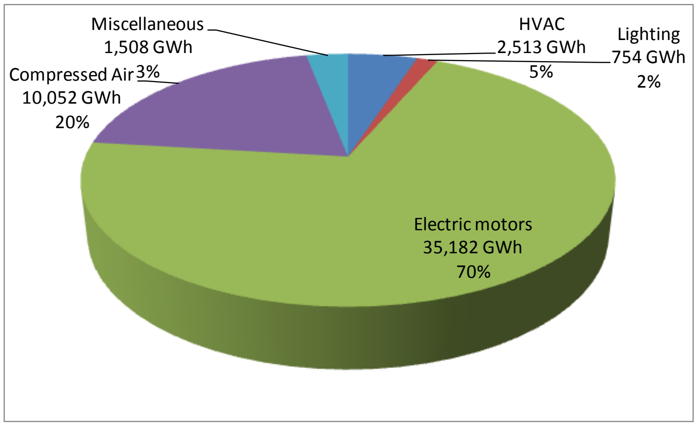


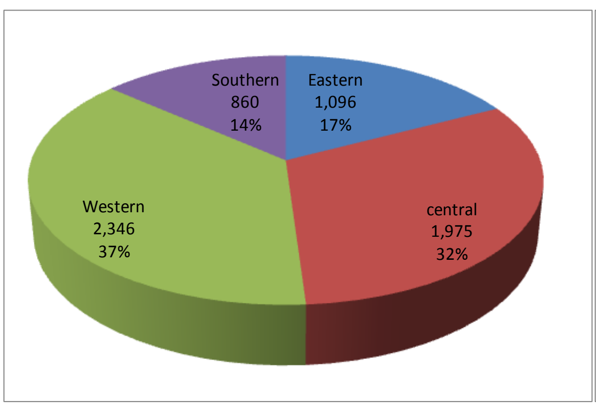
Figure 4-7: 2011 Industrial Energy Consumption by End-Use

4.1.3. Number of Electric Customers

The number of electric customers is an important part of the baseline analysis. These figures serve as the starting point for estimating the number of participants for future DSM programs and initiatives. Derived from data provided by ECRA, there will be an estimated 6.3 million electric customers for KSA in 2011.[46] Using this data set, we calculated the average annual growth rate in customers by region and by sector, and used these values for forecasting the number of customers.[47]

Figure 4-8 illustrates how the number of 2011 electricity customers is segmented by region and sector. The following findings and observations are made from the figure:

- The Central and Western regions account for 70% of the customers.
- The Eastern region, while having a relatively low share of the electric customer population, has a large share of the energy use due to the high concentration of industrial customer.
- The residential sector dominates the customer mix for all regions.



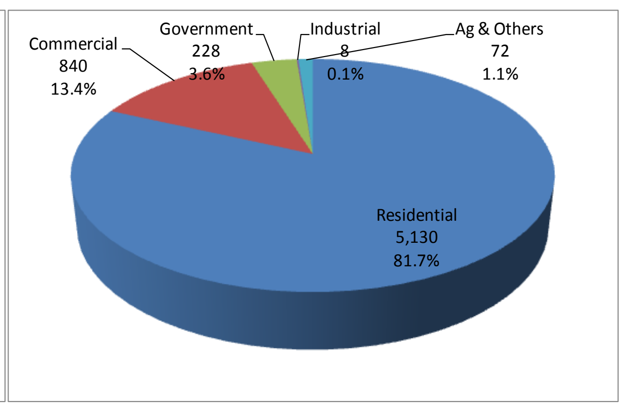


Figure 4-8: Number of Customers (in '000s) by Region and Sector

[46] Data obtained from Excel spreadsheets provided by ECRA which provided number of customers and sales by region and by sector for 2006-2009.

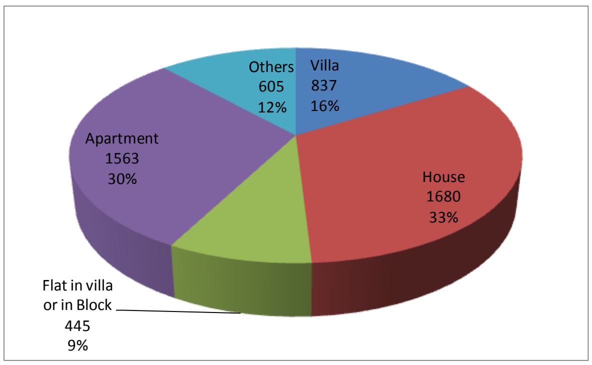
[47] *Ibid.*

Another important indicator of how customers are segmented is to understand the various market segments comprising each of the four sectors (residential, commercial, government and industrial) that are assessed in this study. Figure 4-9 illustrates the number of residential and commercial customers by market segment.[48] The residential sector in the KSA is comprised of the following market segments:

- Villa
- House
- Flat in villa or block
- Apartment
- Others

The commercial sector in the KSA is comprised of the following market segments:

- Hotels
- Restaurants
- Malls and stores
- Offices
- Private hospitals
- Others



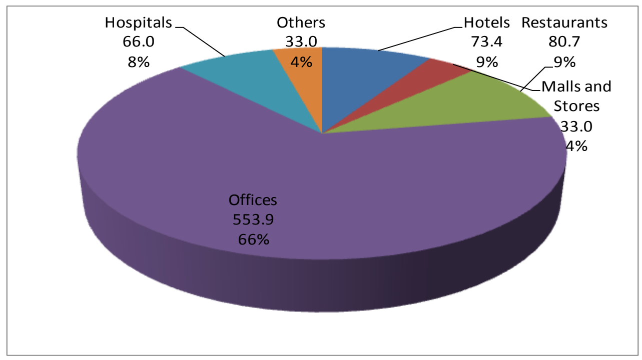


Figure 4-9: Number of Residential and Commercial Customers (in '000s) by Market Segment

Figure 4-10 illustrates the number of government and industrial customers by market segment.[49] The government sector in the KSA is comprised of the following market segments:

- Education (primary schools and universities)
- Ministries
- Government hospitals
- Mosques
- Military
- Street lighting

The industrial sector in the KSA is comprised of the following market segments:

- Food and beverage
- Textiles and leather
- Fiber and furniture
- Paper, printing and publishing
- Chemicals and plastics
- Ceramics
- Basic metals
- Metal products
- Other industries

48 'National Energy Efficiency Program- Final Report; Objective 2- Energy Efficiency Information and Awareness, Volume 2A'

49 *Ibid.*

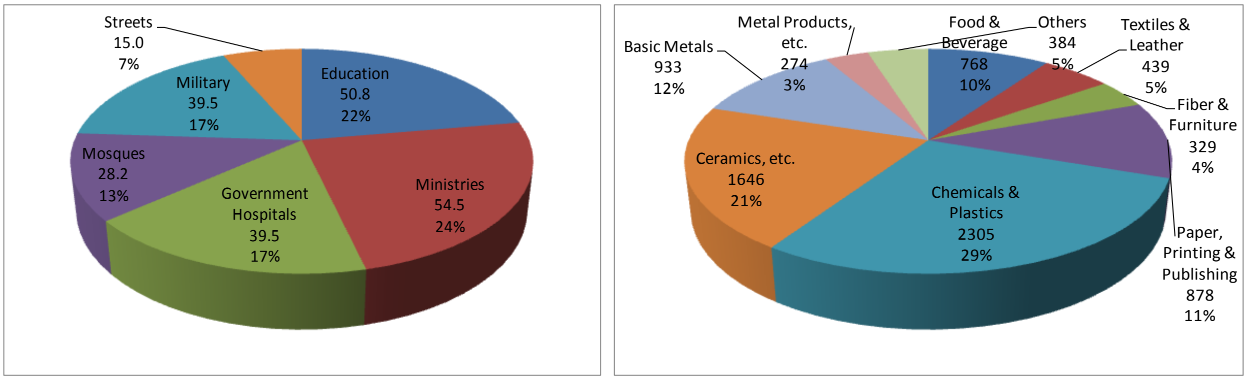


Figure 4-10: Number of Government and Industrial Customers (in '000s) by Market Segment

Table 4-1 indicates how the total electric customer population is segmented according to their size, where size is determined based on average monthly electricity use level. The table presents this information for each of the four sectors. [50]

Table 4-1: Segmentation of Electric Customers based on Size

Size Category	Size Range (based on electricity consumption kWh/month)	% of Total Customers	% of Total Consumption
Residential Sector			
Small	0-5,000	95.4%	76.3%
Medium	5,000-10,000	4.0%	14.1%
Large	> 10,000	0.6%	9.7%
Commercial Sector			
Small	1-5,000	92.2%	49.0%
Medium	5,000-10,000	5.3%	14.0%
Large	> 10,000	2.5%	37.0%
Government Sector			
Small	1-5,000	73.1%	7.1%
Medium	5,000-10,000	11.3%	7.5%
Large	> 10,000	15.6%	85.4%
Industrial Sector			
Small	1-5,000	36.0%	0.3%
Medium	5,000-10,000	14.0%	0.4%
Large	> 10,000	49.0%	99.4%

4.2. BASELINE FORECAST

Prior to developing estimates of DSM potential, a baseline end-use forecast must be prepared to quantify how electricity is used by end use in the reference year and how that consumption will evolve in the future in absence of new DSM programs and initiatives. The baseline forecast

50 *Ibid.*

serves as the metric against which the potential impacts of DSM programs are compared. Three baseline forecast indicators were prepared: peak demand, energy use and number of electric customers. The results of each forecast are presented in the sections that follow.

4.2.1. Peak Demand Forecast

The peak demand forecasts were derived using a combination of electricity sales and load factors. Electricity sales forecasts for the four regions were obtained from a 2010 report by the National Energy Efficiency Program.[51] Sectoral shares in the total energy consumption by region were calculated using data obtained from a 2007 report provided by ECRA.[52] These shares were applied to the regional electricity sales forecast numbers in order to derive electricity sales forecast by region and by sector. The 2007 report also provided average load factors by sector for residential, commercial, government, industrial, and agricultural customers.[53] These load factor values were applied to the sectoral electricity sales forecast to derive sectoral peak demand forecasts.

Table 4-2 presents the peak demand forecast for the period 2011-2021 by sector and region. As can be seen from the table, the peak demand is expected to grow by more than 60% over the eleven-year forecast period. Among all sectors, the industrial peak demand grows the fastest at an average annual growth rate of over 9% for the forecast period. This is due in a large part to projected economic growth. Strong growth is also projected for the commercial and residential sectors, reflecting the increased economic activity for the commercial sector and increased population projections affecting the residential sector. The government sector is expected to grow at a more modest rate of 3% per year. The region showing the most growth is the Southern region, reflecting rapid population growth. The Eastern region shows the most significant growth in peak demand in absolute terms.

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51 '*Volume I- Revised Generation Planning Report- Electricity Generation and Transmission Plan (EGTP)*'; Prepared for Ministry of Water & Electricity (MOWE), Riyadh, Saudi Arabia; January 2010.

52 '*Development of Electricity Generation and Transmission Plan for Saudi Arabia - Electricity Demand Forecast'*; June 2007.

53 *Ibid.* The report indicates the following load factors by sector- Residential: 50%; Commercial: 63%; Industrial: 80%; Governmental: 65%; Agricultural: 60%.

Table 4-2: Peak Demand Forecast by Sector and Region

Sector	Gigawatts (GW)						Avg. Annual Growth	Future Growth '11-'21
	2011	2013	2015	2017	2019	2021		
Residential	27.0	30.1	32.9	35.7	38.8	42.2	5%	56%
Commercial	4.8	5.4	6.1	6.7	7.4	8.4	7%	74%
Government	5.6	6.1	6.5	6.8	7.1	7.5	3%	34%
Industrial	8.2	9.3	10.4	11.6	13.2	15.6	8%	90%
Ag & Others	0.9	1.0	1.0	1.1	1.1	1.2	3%	33%
Total	**46.5**	**52.0**	**56.8**	**61.9**	**67.7**	**74.8**	**6%**	**61%**

Region	Gigawatts (GW)						Avg. Annual Growth	Growth '11-'21
	2011	2013	2015	2017	2019	2021		
Eastern	14.3	15.9	17.4	19.2	21.4	24.5	6%	71%
Central	14.3	15.9	17.2	18.6	20.0	21.5	5%	50%
Western	14.2	15.7	17.0	18.4	19.9	21.6	5%	52%
Southern	3.6	4.5	5.1	5.8	6.5	7.2	9%	98%
Total	**46.5**	**52.0**	**56.8**	**61.9**	**67.7**	**74.8**	**6%**	**61%**

Figure 4-11 graphically illustrates the peak demand forecast by sector. Figure 4-12 graphically illustrates the peak demand forecast by region.

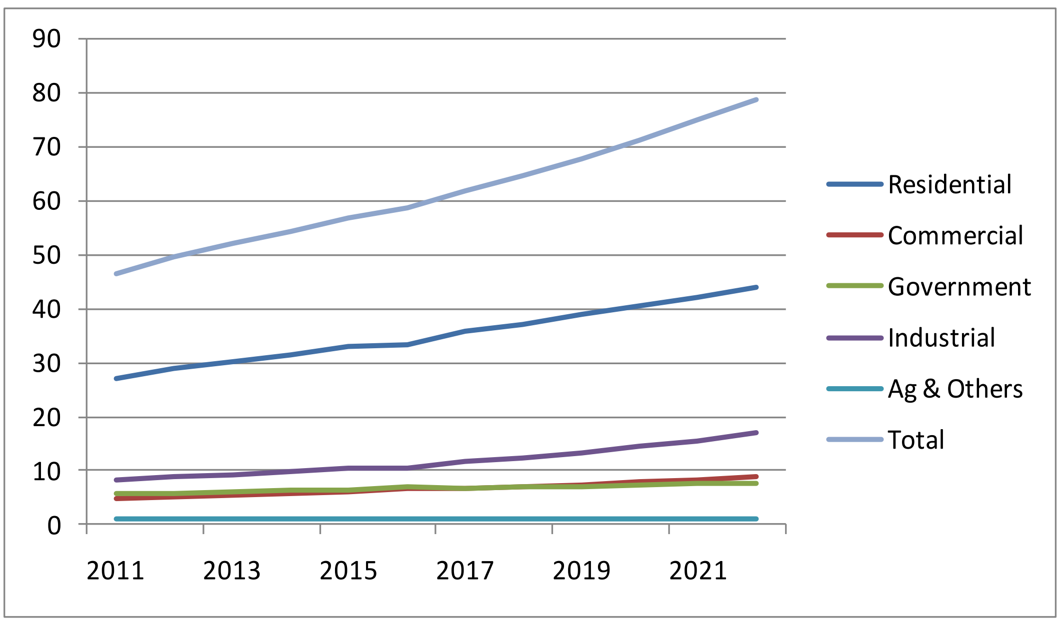

Figure 4-11: Peak Demand (GW) Forecast by Sector

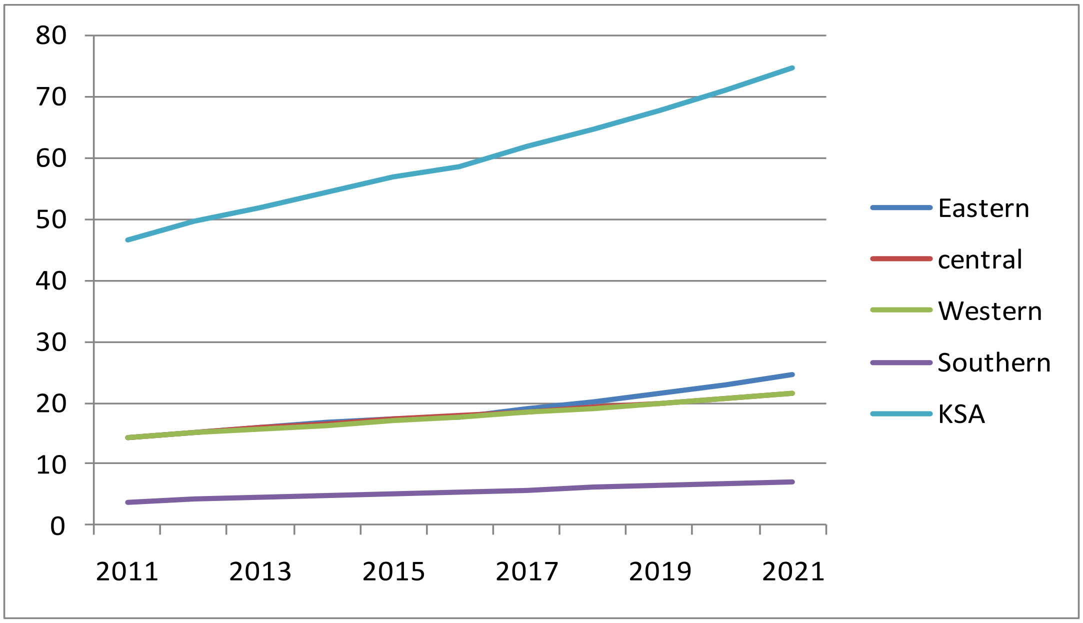

Figure 4-12: Peak Demand (GW) Forecast by Region

4.2.2. Energy Use Forecast

Table 4-3 presents the annual energy use forecast for the period 2011-2021 by sector and region. As described earlier under Section 4.2.1, we applied sectoral shares to the total electricity consumption forecast numbers by region, using data from reports obtained from ECRA.[54]

[54] As indicated earlier, the report titled '*Volume I- Revised Generation Planning Report- Electricity Generation and Transmission Plan (EGTP)*'; Prepared for Ministry of Water & Electricity (MOWE), Riyadh, Saudi Arabia; January 2010' provided regional sales forecast. Sectoral shares in energy use by region was derived using data presented in the report titled- *'Development of Electricity Generation and Transmission Plan for Saudi Arabia - Electricity Demand Forecast*; June 2007.' These shares were then applied to the regional sales forecast to come up with sectoral sales forecast for the four regions.

Table 4-3: Annual Energy Use Forecast by Sector and Region

Sector	Historical Growth ’06-‘09	Gigawatt-hours (GWh) 2011	2013	2015	2017	2019	2021	Avg. Annual Growth	Future Growth '11-'21
Residential	17%	118,522	133,585	145,640	157,866	170,078	185,576	5%	57%
Commercial	38%	26,251	29,996	33,407	37,005	41,025	46,163	7%	76%
Government	21%	31,505	34,434	36,403	38,248	40,028	42,048	3%	33%
Industrial	6%	50,260	57,143	65,163	74,886	86,135	101,932	9%	103%
Ag & Others	50%	4,722	5,185	5,441	5,675	5,897	6,062	3%	28%
Total	**18%**	**231,260**	**260,343**	**286,054**	**313,680**	**343,163**	**381,781**	**6%**	**65%**

Region	Historical Growth ’06-‘09	Gigawatt-hours (GWh) 2011	2013	2015	2017	2019	2021	Avg. Annual Growth	Future Growth '11-'21
Eastern	9%	74,429	82,888	92,885	104,837	118,241	136,395	8%	83%
Central	21%	68,589	77,055	82,566	89,123	95,963	103,761	5%	51%
Western	24%	67,579	74,766	81,262	84,789	91,904	100,536	4%	49%
Southern	27%	20,663	25,634	29,341	34,931	37,055	41,089	9%	99%
Total	**18%**	**231,260**	**260,343**	**286,054**	**313,680**	**343,163**	**381,781**	**6%**	**65%**

As can be seen from the table, energy use is projected to grow by almost two-thirds in the eleven-year forecast period. Much of that growth is driven by industrial and residential sectors. The key growth drivers for energy are the same as for peak demand: significant population growth and strong economic expansion.

Figure 4-13 graphically illustrates the energy use forecast by sector. Figure 4-14 graphically illustrates the energy use forecast by region.

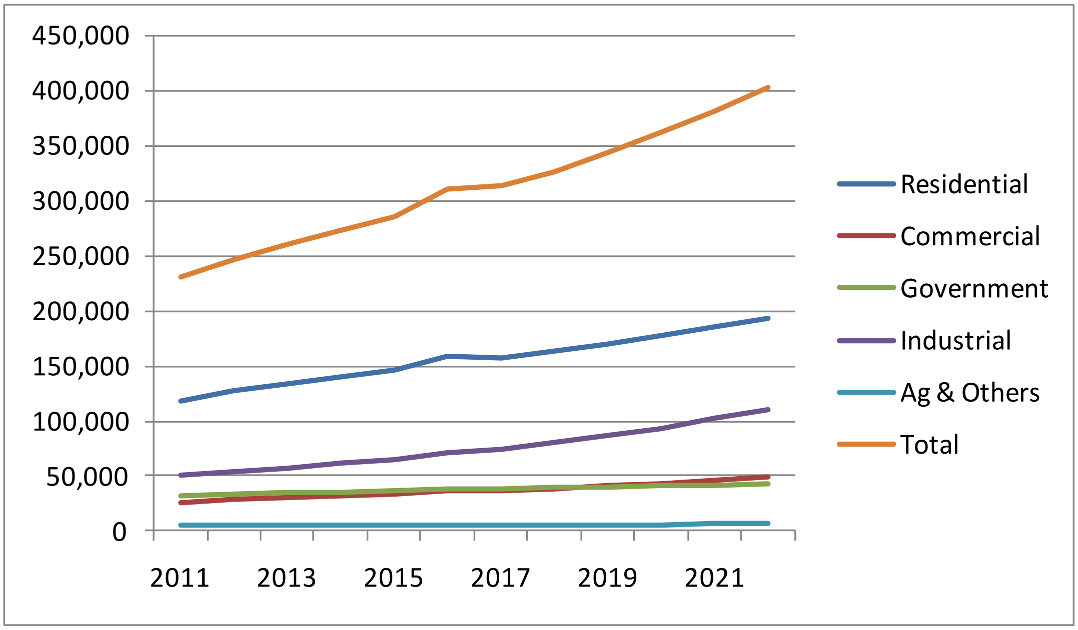

Figure 4-13: Energy Use (GWh) Forecast by Sector

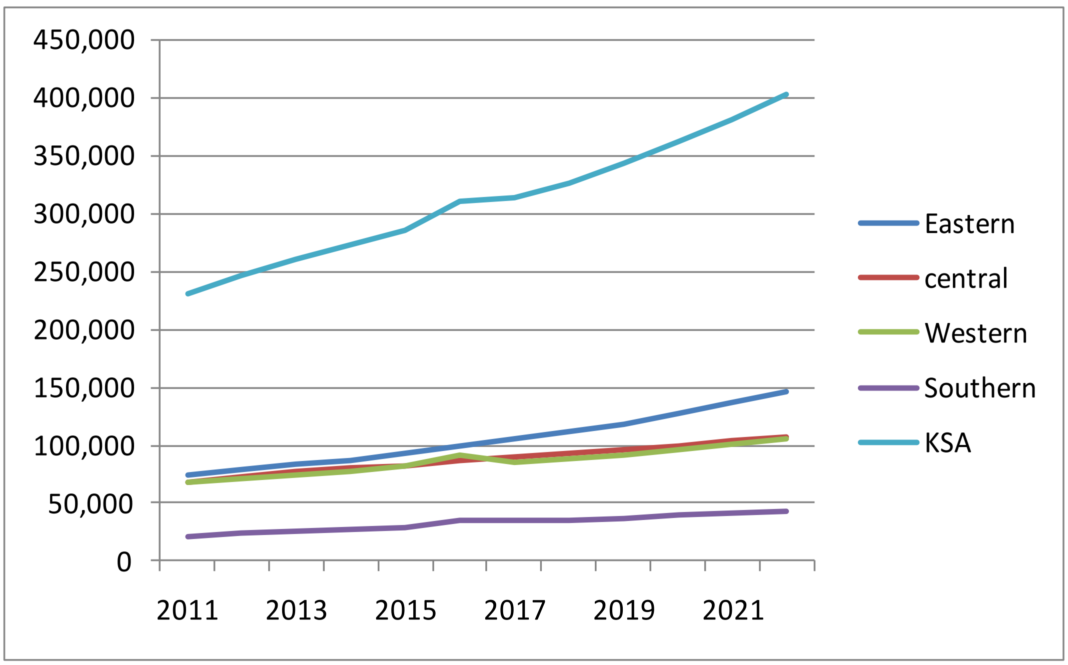

Figure 4-14: Energy Use (GWh) Forecast by Region

4.2.3. Electric Customer Forecast

Table 4-4 presents the forecast number of electric customers for select years during the period 2011-2021 by sector and region. Using data provided by ECRA, we calculated the average annual growth rate in customers by region and by sector, and used these values for forecasting the number of customers.[55] The table reveals that overall there will be a 63% increase in the number of electric customers in the KSA. Most of the growth in the number of customers is coming from the government sector. However, it is interesting to point out that this growth in number of customers is not correlated with the growth in energy use or peak demand, which is driven by Residential and Industrial sectors. Finally, the Southern region is growing their customer base most rapidly, in percentage terms.

Table 4-4: Forecast Number of Electric Customers by Sector and Region

	Number of Electric Customers ('000)						Avg.	
Sector	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**Annual Growth**	**Growth '11-'21**
Residential	5,130	5,631	6,183	6,792	7,463	8,203	5%	60%
Commercial	840	937	1,047	1,170	1,308	1,464	7%	74%
Government	228	264	308	358	416	485	10%	113%
Industrial	8	9	10	10	12	13	5%	60%
Ag & Others	72	75	79	83	88	94	3%	31%
Total	**6,278**	**6,917**	**7,626**	**8,413**	**9,287**	**10,259**	**6%**	**63%**

	Number of Electric Customers ('000)						Avg.	
Region	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**Annual Growth**	**Growth '11-'21**
Eastern	1,096	1,220	1,357	1,510	1,680	1,870	6%	71%
Central	1,975	2,178	2,402	2,651	2,927	3,234	6%	64%
Western	2,346	2,540	2,750	2,980	3,230	3,502	4%	49%
Southern	860	980	1,117	1,273	1,451	1,653	8%	92%
Total	**6,278**	**6,917**	**7,626**	**8,413**	**9,287**	**10,259**	**6%**	**63%**

4.3. Avoided Costs

The primary benefit of DSM measures is that they modify the system load profile in such a way that overall system costs are reduced. The need to invest in new infrastructure is lessened or deferred, and the variable cost of operating existing units is avoided. We consider three types of supply-side costs that are potentially avoided through demand-side activity: generating capacity costs, transmission and distribution (T&D) costs, and energy costs.

4.3.1. Generating Capacity Costs

As peak demand is reduced through DSM initiatives, the need to build new peaking units that would otherwise serve that demand is avoided or deferred. This is a particularly relevant benefit in the KSA, where peak demand is expected to grow in excess of five percent per year and over 4,000 MW of peaking capacity is expected to be added in the next decade.[56]

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[55] Data obtained from Excel spreadsheets provided by ECRA which provided number of customers and sales by region and by sector for 2006-2009.

[56] See Chapter 5 for further discussion of this estimate.

Our analysis assumes that the avoided cost of capacity is ***236 SR/kW-year***.[57] This is the full levelized installation cost (plus interest during construction) of a combustion turbine unit as provided by ECRA, but derated by 30 percent to account for the following factors:[58]

- If the peaking unit had been built, it would have provided some energy value through sales into the market during non-event hours. This energy value is not captured by the DSM program and is netted out of the cost of the peaker.
- There is some level of uncertainty around the ability of LM/DR programs to provide demand reductions during the actual hour of the system peak. This is because the timing of the system peak is not predictable with 100 percent foresight. A downward adjustment is made to the avoided cost to reflect the actual likelihood of capturing the system peak.
- There are operational limits on LM/DR programs that limit their ability to capture the system peak with certainty. For example, LM/DR measures typically include a cap on the number of critical events that can be called during any given summer. Additionally, the timing of the peak period in these measures is often restricted to a specific window of time. The avoided cost estimate is adjusted downward to account for these limitations.

4.3.2. T&D Capacity Costs

Reductions in peak demand also reduce the need to expand the T&D system. A portion of T&D investment is driven by the need to have enough capacity available to move electricity to where it is needed during peak times while maintaining a sufficient level of reliability. Additionally, geographic expansion of the system requires T&D investment, and that is often correlated to growth in peak demand.

However, there are also aspects of T&D system expansion that are not driven by growth in peak demand. For example, some reliability-driven projects are built to ensure that enough capacity is available to address congestion during mid-peak and off-peak periods. Other projects are driven to integrate new generation additions which may be built as baseload resources rather than peaking generation. As a result, when calculating avoided costs for valuing LM/DR programs, utilities will often calculate the total amount of expected T&D infrastructure investment and then derate it to account for the share of that investment that is driven by peak demand.

Utility estimates of avoided T&D costs vary significantly and are very system specific. In a review of utility DR filings and marginal cost studies, and interviews with utility engineers, avoided T&D costs generally ranged from 0 to 190 SR/kW-yr.[59] A common rule of thumb

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57 ECRA provided an installation cost of 2,500 SR/kW. This was increased by 15% to account for interest during construction, and then levelized using a 10% discount rate and 20-year unit life. This value is consistent with the assumptions used recently by several other utilities in DR business case filings. See, for example, the Southern California Edison business case, which used an installation cost assumption of $75/kW-yr for a peaking unit. The U.S. Energy Information Administration uses an estimate of $665/kW in its modeling efforts.

58 30% is a value commonly used by the investor-owned utilities in California and accepted by the California Public Utilities Commission. It was originally derived by Southern California Edison, one of the global leaders in demand response, using the so-called "A times B method," which accounts for the factors described in this section. Similar methods are used by several other utilities in the United States.

59 For example, Pepco Holdings excluded any T&D benefits from the LM/DR component of its AMI business case filing. A confidential marginal cost study for a utility in the Eastern U.S. found the marginal T&D costs driven by demand during peak hours to be in excess of $60/kW-year.

among utilities was to assume that 20 percent of the total T&D system cost was driven by peak demand. Using this same rule of thumb for the KSA and applying it to T&D system cost estimates provided by ECRA (on a levelized basis) puts our estimate of avoided T&D costs right in the middle of that range, at **85 SR/kW-yr**.[60] This benchmarking suggests that it is a reasonable estimate for the KSA. However, as noted, due to the system-specific nature of these estimates, this is an area where further research is warranted.[61]

4.3.3. Energy Costs

Reductions in consumption will avoid the marginal cost of generating electricity (mostly fuel costs). This is typically a primary benefit of energy efficiency programs, which derive most of their value from overall reductions in consumption. For LM/DR programs, avoided energy cost benefits make less of a contribution to the total benefit, since consumption reductions are concentrated in a small number of hours in the year.

Avoided energy costs are a time-dependent input to our analysis. Reductions during peak times avoid a higher marginal cost, because less efficient generating units are on the margin during these times. These costs also vary by season for the same reason – in the summer, when demand is higher, energy prices also tend to be higher. For our analysis, we have used Saudi-specific energy costs provided by ECRA, unadjusted. These are **60 SR/MWh** in the summer peak, **50 SR/MWh** in the summer off-peak, **40 SR/MWh** in the winter peak, and **35 SR/MWh** in the winter off-peak.

It is important to note that these prices are significantly lower than their equivalent in many other parts of the world (roughly 80 to 90 percent lower). This is because of the KSA's heavily discounted oil price, which accounts for roughly 2/3 of the country's electricity generation. From one perspective, using these energy prices understates the cost to the KSA, because there is an opportunity cost associated with using oil to produce electricity domestically rather than to sell it at a much higher price on the world market. This can have a dramatic effect on the conclusions of our analysis and is discussed further in Chapter 7.

4.4. Segment Load Shapes

At the time of writing this report, hourly load profiles by customer class were not available.[62] The most definitive information about customer class-level consumption patterns are estimates of class load factors, which were used to estimate each major customer segment's contribution to the system peak (as described earlier in this chapter). However, hourly load profiles for these segments can still be approximated to some extent by analyzing load data at the substation level. Substations were selected from locations on the SEC grid that are dominated by load from one of three segments: residential, commercial, or industrial. This load data was provided for one or

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60 ECRA provided an estimate of 3,600 SR/kW in expected T&D investment. This was levelized using a 10% discount rate and 20-year unit life. Then, the 80% derate factor was applied.

61 Stakeholders expressed a range of views regarding the appropriate factor for derating expected T&D investment. Some felt that the derate factor should be lower. 80% is used in our analysis in order to be conservative and to avoid overstating the potential benefits of LM/DR.

62 This is important data that must be collected in order to conduct a more refined assessment of LM/DR programs.

two summer months (July and August) in 2010. Using this data, graphical depictions of hourly consumption profiles on a typical summer weekday were developed for each customer segment. These are illustrated, on a normalized basis, in Figure 4-15.[63] Additional information on the load shapes and how they were developed is provided in Appendix B.

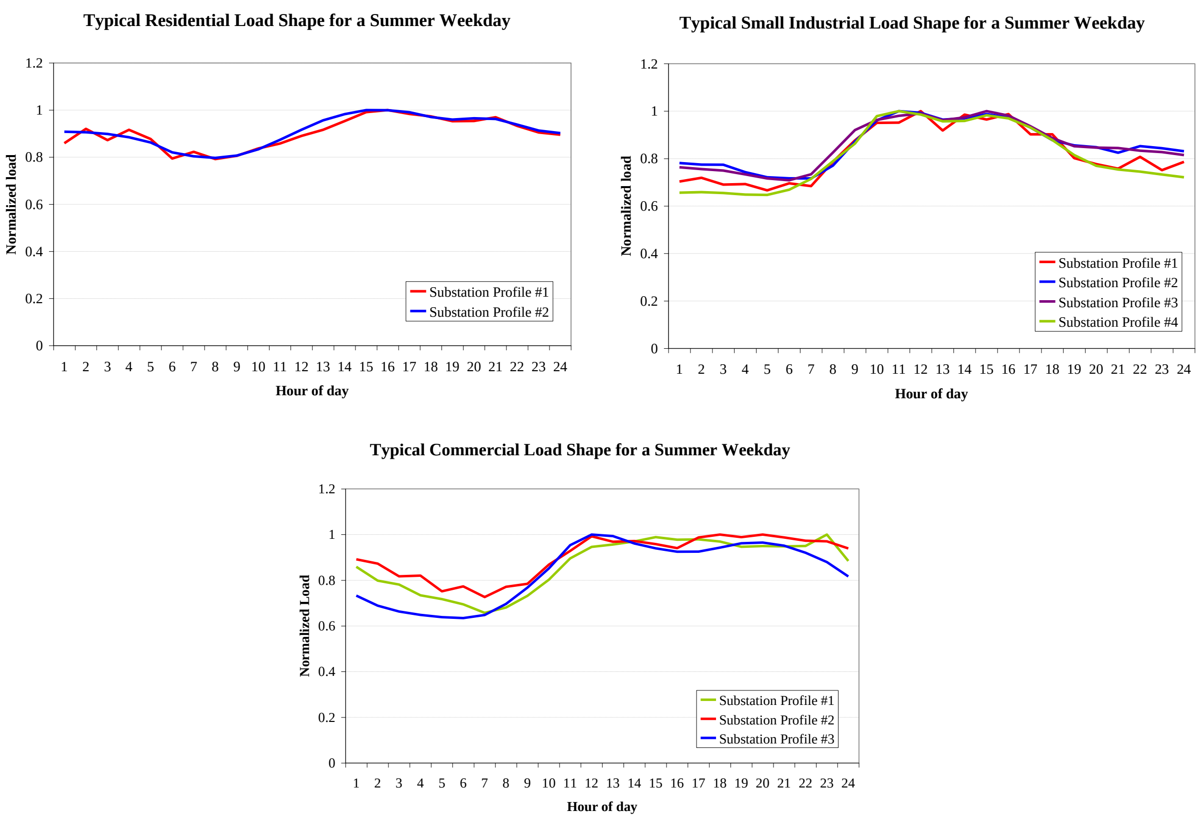

Figure 4-15: Typical Load Profiles by Customer Segment

The load profiles suggest that the small industrial segment has an earlier and more pronounced peak that generally spans the period from 10 am to 6 pm. Load in the commercial segment ramps up around noon, presumably as retail stores commence operation, and remains at or near peak levels throughout the remainder of the day. Commercial load remains at a high level through midnight, which is a common closing time for retail stores and malls in the KSA. Notably, customer segments exhibit significant consumption levels during off-peak hours, which could be explained by the continued use of air-conditioning and lighting at these facilities.

A similar pattern is seen in the residential data, although the ramp up occurs slightly later as residents return home from work. The rise in load around 3 pm could be explained by the emphasis of Saudi citizens on lunch as the most important occasion for family gathering. Additionally, the continued high level of consumption into later hours of the night is consistent with the Saudi lifestyle, which includes late dinners and other activities.[64]

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63 Data was provided by ECRA and SEC and cleaned to address issues such as missing observations.

64 JICA, "The Master Plan Study for Energy Conservation in the Power Sector in the Kingdom of Saudi Arabia," July 2008, p. 163.

The flat shape of the hourly usage profiles may also be attributable to the load data not being entirely composed of consumption from one customer class, as there is no single substation that serves an entirely homogeneous population of customers. And, as noted earlier, this substation load data represents load at a few specific points on the grid, rather than necessarily being representative of each segment as a whole across the entire system. Therefore, these load profiles are provided for contextual purposes, to serve as an illustration of likely class consumption patterns and it is because of that limitation that they do not serve as the basis for empirical work in our study.

4.6. THE SYSTEM LOAD SHAPE

The hourly shape of system load is a key consideration in LM/DR planning. Hourly 2009 SEC load shows a moderate load factor and strong seasonal variation.[65] The load factor, or average demand divided by peak demand, was 65 percent.[66] The system peaked on August 22 with a load of 38.1 GW. The average summer demand was 31.9 GW while the average non-summer demand was only 21.3 GW. Total generation throughout the entire year was 218 terawatt-hours (TWh). These summary statistics, as well as the statistics for each of SEC's four operating areas, are shown in Table 4-5.

Table 4-5: 2009 Load Profile Characteristics by Operating Area

	East	Central	West	South	All SEC
Peak Demand (GW)	11.6	12.5	11.3	3.0	**38.1**
Total Sales (TWh)	71	64	63	19	**218**
Load Factor	70%	59%	64%	72%	**65%**
Average Summer Demand (Jun. - Sept.) (GW)	10.0	10.1	9.3	2.5	**31.9**
Average Non-Summer Demand (GW)	7.2	6.0	6.2	1.9	**21.3**

Source: Load data provided by ECRA/SEC

Figure 4-16 displays the system load chronologically throughout the year, highlighting the substantial seasonal variation in consumption. In 2009, the summer months between June and October had consistently higher loads than the non-summer months, primarily due to air-conditioning load.

[65] 2009 data is shown as an example here, because it was the latest available data at the time that the analysis was conducted. A review of 2010 load data shows an identical system load factor and a similar seasonal pattern.

[66] This load factor is calculated directly from hourly load data provided by ECRA. Estimates from other sources sometimes suggest a lower load factor for the KSA. This discrepancy is an issue that should be resolved through future load research.

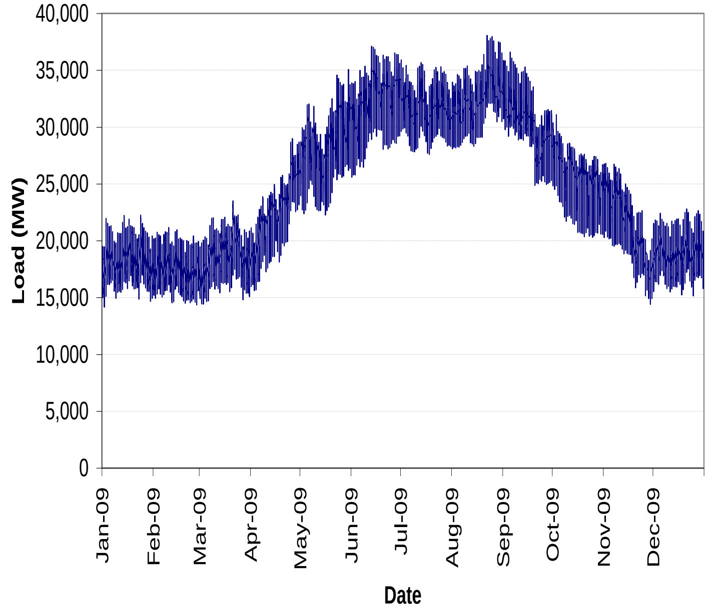

Figure 4-16: 2009 SEC System Load (Chronological)

The same seasonal pattern exists in the central, east, and west operating areas. In the south operating area, where load is much lower, the load shape is noticeably flatter over the course of the year. Hourly load data for each of the four operating areas in 2009 is illustrated in Figure 4-17.

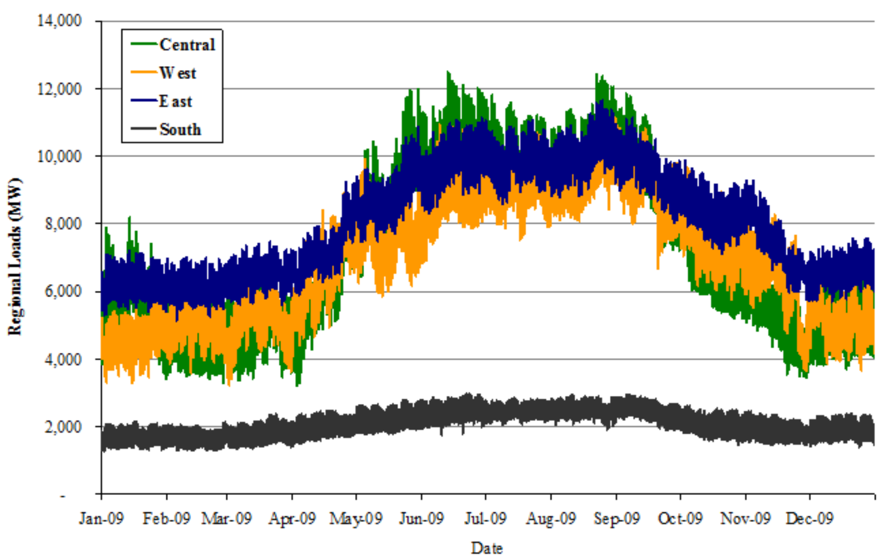

Figure 4-17: 2009 Hourly Load by Operating Area

The daily load curve shows significantly higher consumption on weekdays than on weekends, and as seen in the previous illustrations, much higher consumption during the summer months. Average daily system load shapes are illustrated in Figure 4-18.

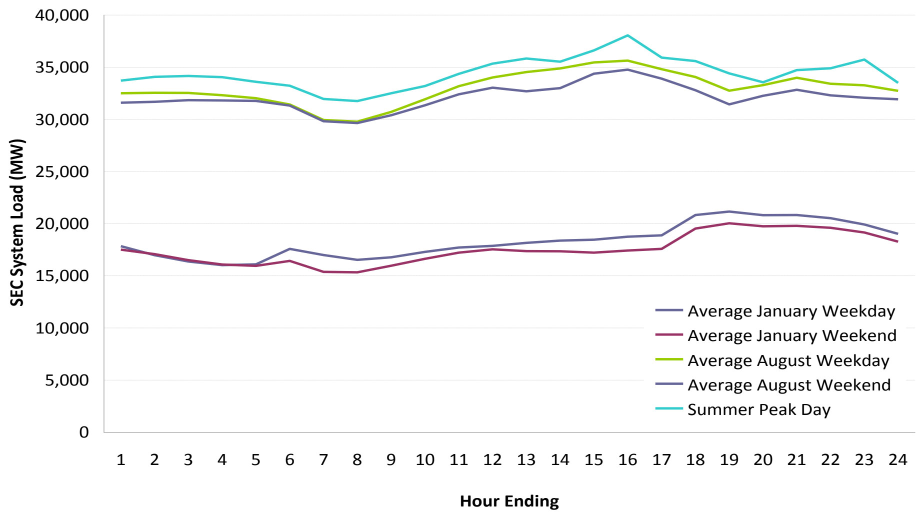

Figure 4-18: 2009 Average System Daily Load Shapes

The focus of this report is on identifying ways to reduce the rapid growth in peak demand that is expected to occur in the KSA over the next decade. Therefore, the highest load hours are particularly of interest. Figure 4-19 shows the top five hundred hours of the year, sorted from highest to lowest. Viewing the load curve in this way reveals that a significant amount of load is attributable to a limited number of hours of the year. Ultimately, it is consumption in these top hours (or a subset of these hours) that will need to be reduced through LM/DR programs in order to achieve meaningful impacts.

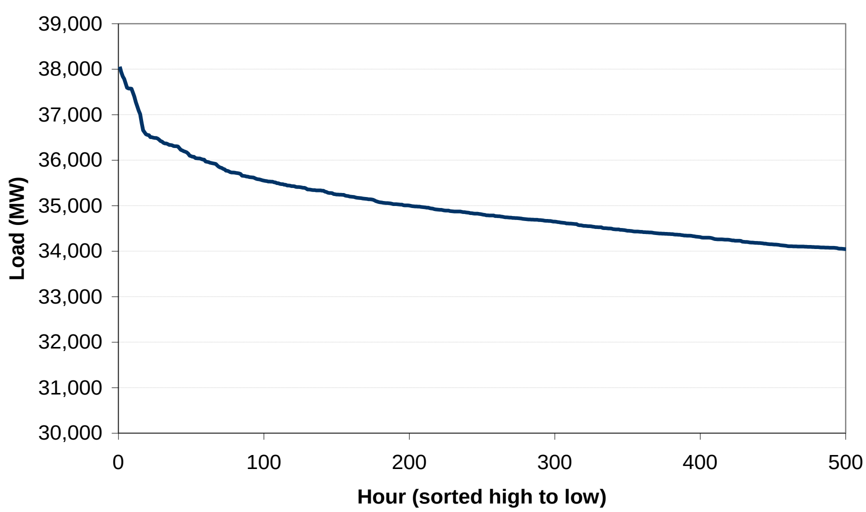

Figure 4-19: 2009 SEC Load Duration Curve (Top 500 Hours)

Compared to some other regions, the KSA load duration curve is relatively "flat." In other words, there is a large number of hours with high load in the summer, rather than a very small number of hours in which that high load is concentrated. For example, the figure below shows that peak load in Arizona (in the hot and dry Southwestern United States) is concentrated in a smaller number of hours than in the KSA. Vermont, on the other hand, which is in a more mild region of the U.S and has a lower saturation of air conditioning, has a flatter load curve. Also note the very high load factor in Marafiq's service territory.[67] This is due to the very high concentration of industrial load in the region. For illustration, the SEC and Marafiq load duration curves are compared to those of other regions in Figure 4-20.

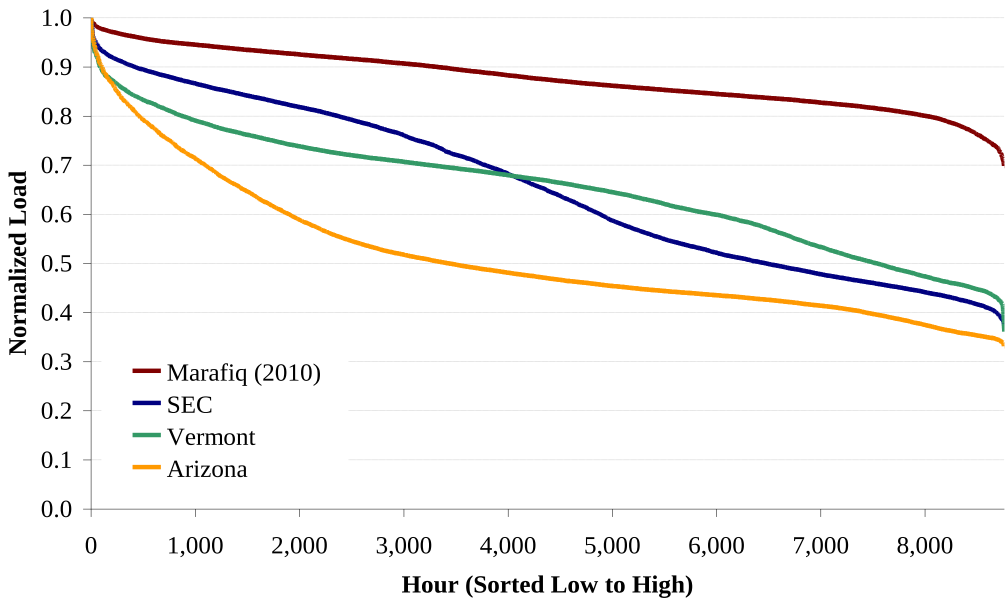

Figure 4-20: 2009 Load Duration Curves

Further analysis of the load duration curve can provide helpful insight regarding the potential effectiveness of LM/DR programs in the KSA. This is the topic of Chapter 5.

67 Marafiq data was provided for 2010.

5. LM/DR FEASIBILITY ANALYSIS

The ability of LM/DR measures to effectively reduce peak demand in the KSA will depend heavily on the shape of the system load profile. A region with a "peaky" load profile, with high consumption concentrated in a small number of peak hours, is a candidate for potentially significant peak reductions from LM/DR programs, because these programs are specifically designed to target demand reductions in those top 50 or 100 hours. Alternatively, a region with a "flat" load profile is less likely to achieve significant peak load reductions from LM/DR and would likely find energy efficiency programs to be more effective. The purpose of this analysis is to use KSA load data to determine feasible peak reduction targets for LM/DR programs, and to identify general design characteristics for successful LM/DR programs in the Kingdom.

5.1. ASSESSING FEASIBLE IMPACTS FROM LM/DR PROGRAMS

In order to reduce peak demand to a certain level, load will need to be reduced not just in the hour of the system peak, but also in other hours of high load. Otherwise, the reduction in the system peak hour could be large but ineffective since these other high load hours would become the new peak. In other words, the larger the desired reduction in system peak, the more hours must be impacted by an LM/DR program.

Using the 2009 system load data, we can observe what would be necessary to achieve a five percent reduction in peak demand in the KSA.[68] To reduce the peak from 38.1 GW to 36.2 GW, 47 hours would need to be impacted by LM/DR. In other words, only 47 hours of the year in 2009 had peak loads greater than 36.2 GW. This is illustrated in Figure 5-1.

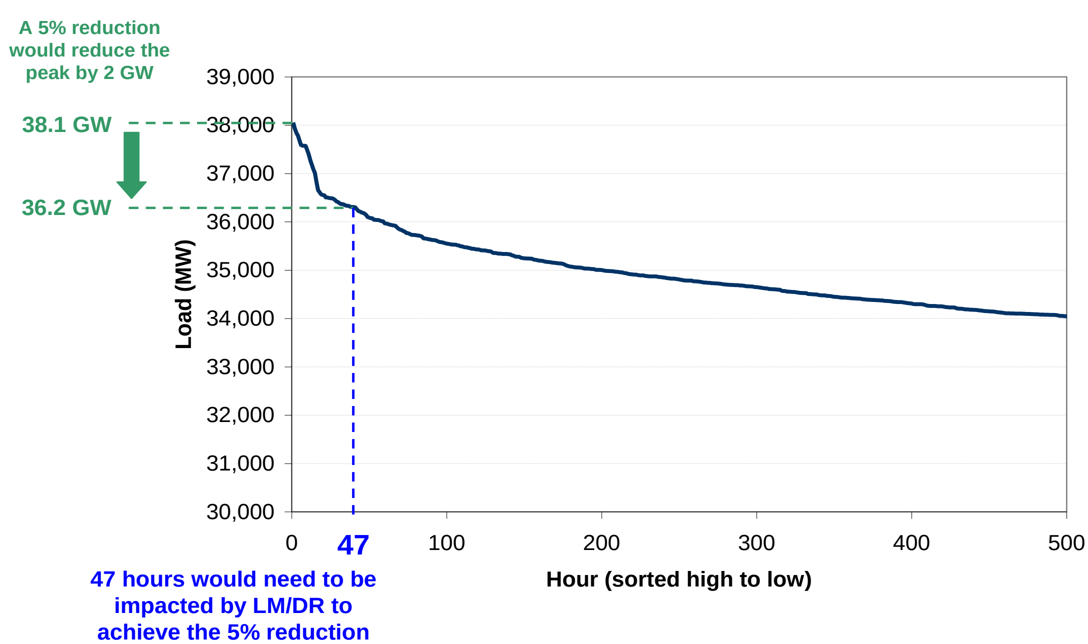

Figure 5-1: Achieving a Five Percent Reduction in System Load

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68 2009 data was used in this example, because it was the most recent data available at the time the analysis was being conducted. The results of this analysis for 2010 data, which more recently became available, are summarized later in this chapter.

It is striking that only 47 hours would need to be impacted by an LM/DR program in order to reduce peak load by 2,000 MW (roughly the equivalent of 20 peaking units). However, a relevant question is how many days and months these 47 hours are spread across. Table 5-1 lists the dates and times.

Table 5-1: The Top 47 "Critical Hours" in 2009

Hour Rank	Date	Hour	Load (GW)
1	8/22/2009	15	38.1
2	8/25/2009	15	37.9
3	8/25/2009	14	37.8
4	8/24/2009	15	37.8
5	8/24/2009	14	37.7
6	8/23/2009	15	37.6
7	8/23/2009	14	37.6
8	8/26/2009	15	37.6
9	8/26/2009	14	37.6
10	8/29/2009	15	37.5
11	8/30/2009	15	37.4
12	8/29/2009	14	37.3
13	8/30/2009	14	37.2
14	6/13/2009	15	37.1
15	6/14/2009	15	37.0
16	6/15/2009	15	36.8
17	8/25/2009	16	36.7
18	8/22/2009	14	36.6
19	9/5/2009	14	36.6
20	8/27/2009	14	36.6
21	8/24/2009	16	36.5
22	6/15/2009	14	36.5
23	6/27/2009	15	36.5
24	8/25/2009	13	36.5
25	8/27/2009	15	36.5
26	8/31/2009	15	36.5
27	6/27/2009	14	36.5
28	8/23/2009	16	36.5
29	8/24/2009	13	36.4
30	9/5/2009	15	36.4
31	6/14/2009	14	36.4
32	6/28/2009	14	36.4
33	6/29/2009	15	36.4
34	8/20/2009	15	36.4
35	8/31/2009	14	36.3
36	8/29/2009	16	36.3
37	6/29/2009	14	36.3
38	8/30/2009	13	36.3
39	6/20/2009	15	36.3
40	6/28/2009	15	36.3
41	6/16/2009	15	36.3
42	8/26/2009	16	36.3
43	6/13/2009	14	36.2
44	8/23/2009	13	36.2
45	6/17/2009	15	36.2
46	6/23/2009	14	36.2
47	6/22/2009	15	36.2

The hours appear to cluster primarily in the months of June and August. Often, more than one of these top 47 hours occurs on the same day, within a fairly narrow window of time. The 47 hours are identified on the chronological system load shown in Figure 5-2.

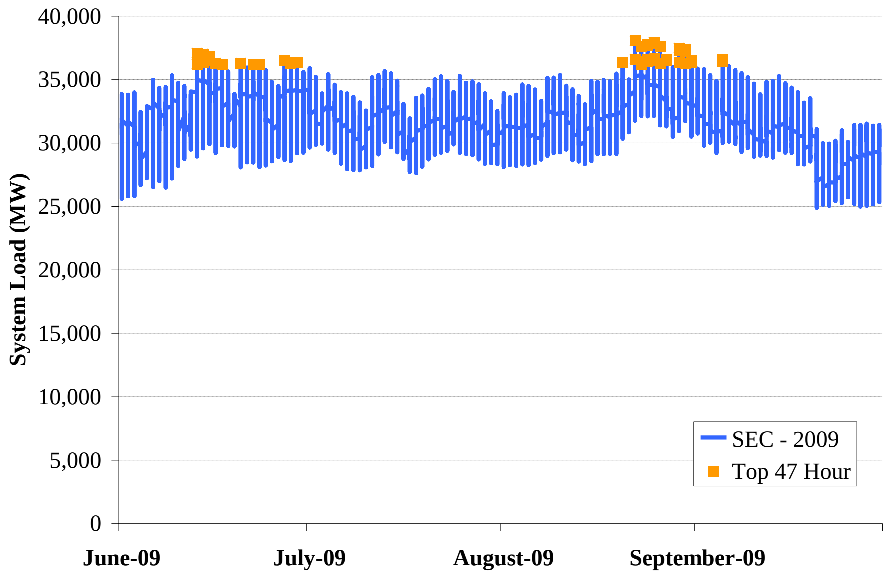


Figure 5-2: 2009 SEC System Load with Top 47 Hours Identified

By focusing on one summer week, it is apparent that the top load hours tend to cluster around a limited number of days, and several of the top hours occur on the same days. This is illustrated in Figure 5-3.

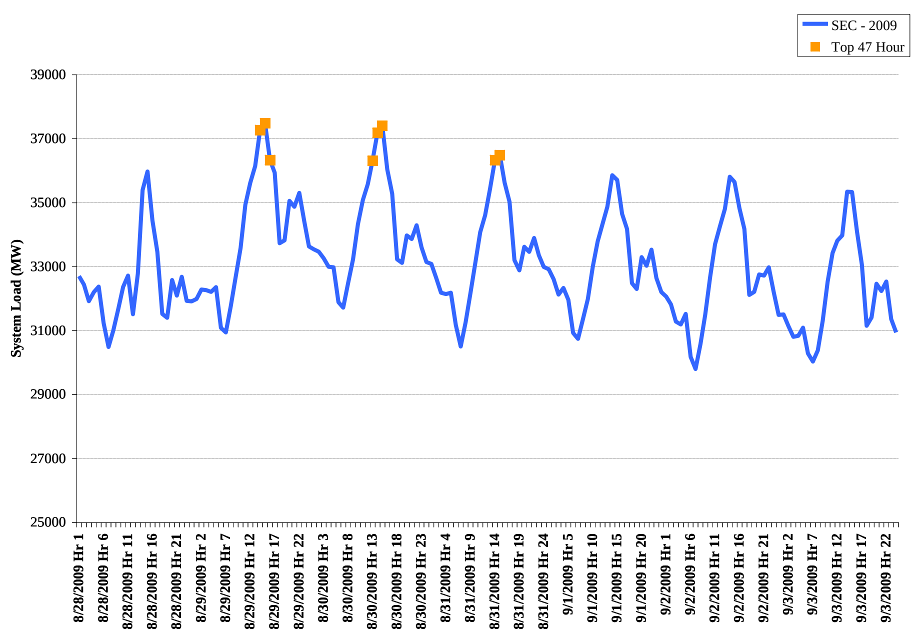


Figure 5-3: 2009 SEC System Load During Summer Week

Notably, all 47 hours fall between noon and 4 pm. They occur on 22 different days, which include all weekdays except for Fridays. The 47 hours all fall within three summer months: June, August, and September. Table 5-2 summarizes these results.

Table 5-2: Summary of Analysis for 5 Percent Peak Reduction in 2009

	Total	Range
Critical hours	47 hours	Noon to 4 pm
Critical days	22 days	Every day except Friday
Critical months	3 months	June, August, September

Given these results, a five percent system peak reduction would have been feasible in 2009. An effective program (or programs) could have targeted the hours from noon to 4 pm and focused on the four month summer period from June through September. These are common characteristics of many LM/DR programs in operation today.

In the future, the occurrence of the critical hours may be affected by the timing of Ramadan. In 2009 Ramadan began in late August and continued into September. Each year, the month of Ramadan starts 10 days earlier. To the extent that electricity usage is higher during Ramadan, some critical hours may be likely to move into early August or July in the coming years.

The program would also need to have been dispatched 20 to 25 times during that four month period (or possibly more due to an imperfect ability to predict peak days). This is at the upper-end of the range of events that can be expected from a LM/DR program. However, it is still a feasible target given proper management of customer expectations, sufficient incentives, and intelligent dispatching of events. For example, half of the program participants could be notified of DR events on 10 days, and the other half of participants could be notified of events on 10 other days (thus spanning a 20 day period). It may be necessary to "oversize" the LM/DR portfolio and dispatch LM/DR events during a greater number of hours in order to address uncertainty and increase the likelihood that a five percent peak reduction will be achieved.

As a rule of thumb, 20 to 25 critical days per summer is the upper limit for effective LM/DR programs. Achieving a 10 percent peak reduction with DR, for example, would require load reductions on more than 400 critical hours spread over 80 critical days. Those types of impacts are not achievable through LM/DR programs. However, impacts of this magnitude could be achieved through a combination of LM/DR, energy efficiency (EE), and Permanent Load Shifting (PLS). EE and PLS programs are designed to target a much broader number of hours of the year. Figure 5-4 shows the number of critical days and hours that would be needed to meet various peak reduction targets.

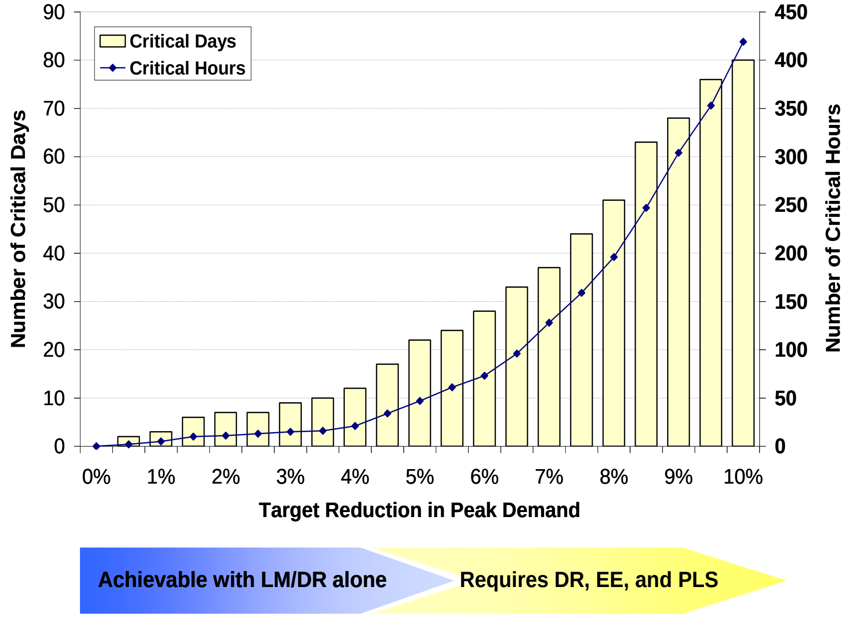


Figure 5-4: Number of Critical Days and Hours Needed to Meet Peak Reduction Targets

5.2. Impacts Across Multiple Years and Regions

Thus far, our analysis has focused on one year (2009) and on the aggregate system load profile. However, we can also look at multiple years of load data (2007 through 2010) across four regions of Saudi Arabia (East, Central, West, and South). This analysis is helpful to understand the degree to which there is year-to-year variation in the results, and whether LM/DR programs should be tailored at the regional level.

The number of critical hours required to achieve a five percent peak reduction varies by region and by year, as shown in Figure 5-5. The Southern region's flat load profile requires that a much larger number of hours be impacted than in the other regions. In the Southern region in 2008, load during 261 hours would have had needed to be reduced to achieve the five percent reduction. This is because the Southern region is dominated by residential load, and around-the-clock use of air-conditioning is most likely a driver of the flat summer consumption profile.

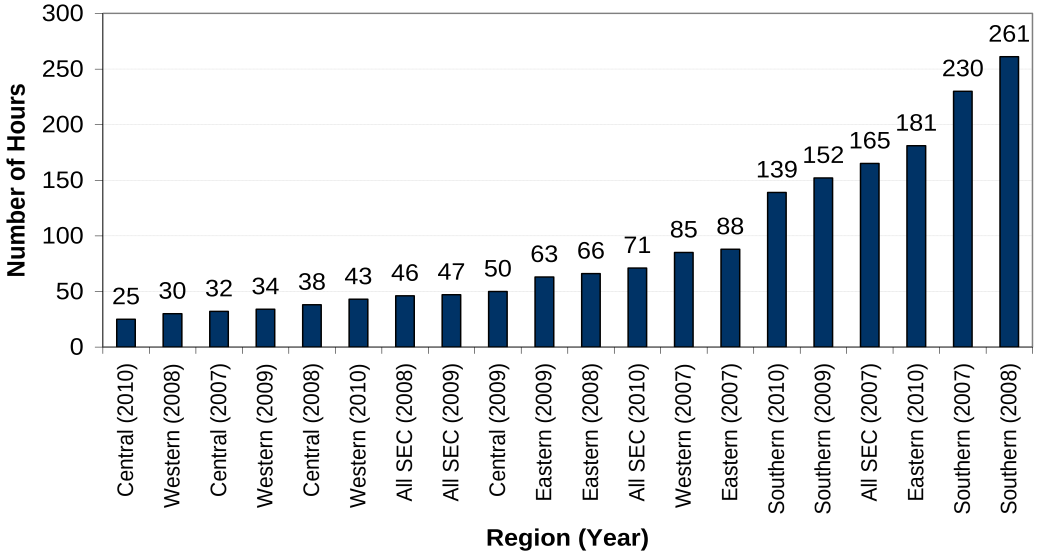


Figure 5-5: Number of Hours that Must be Impacted to Achieve 5 Percent Peak Reduction

The pattern seen in the number of critical days is similar. The Southern region would need more DR events than the other regions to achieve the same target. Additionally, in 2007, more hours and more critical days would be needed to achieve the same result, indicating that the 2007 load shapes were flatter than the other two years. A summary of the analysis for 2007 through 2010 is provided in Appendix C.

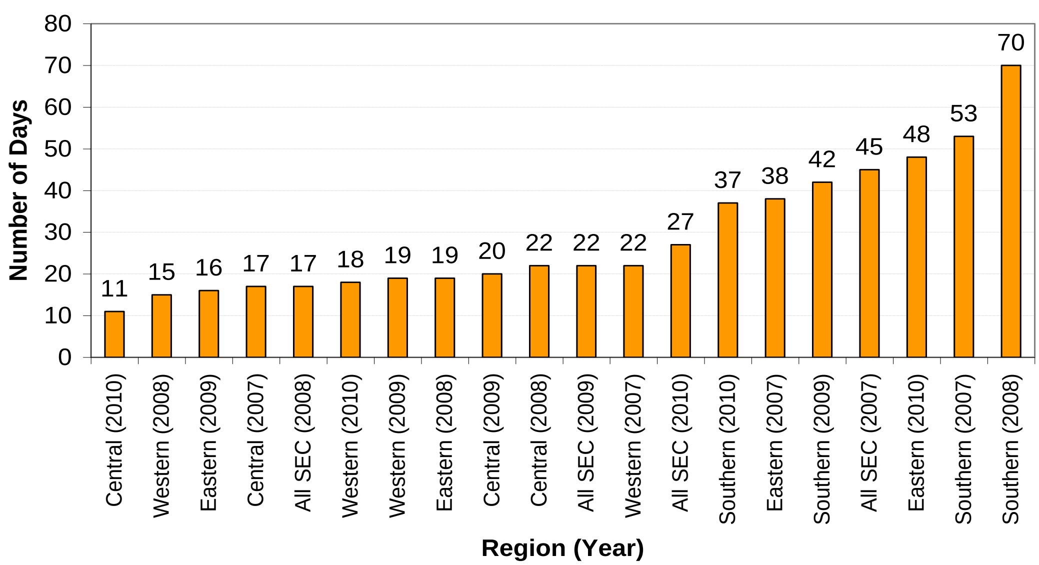
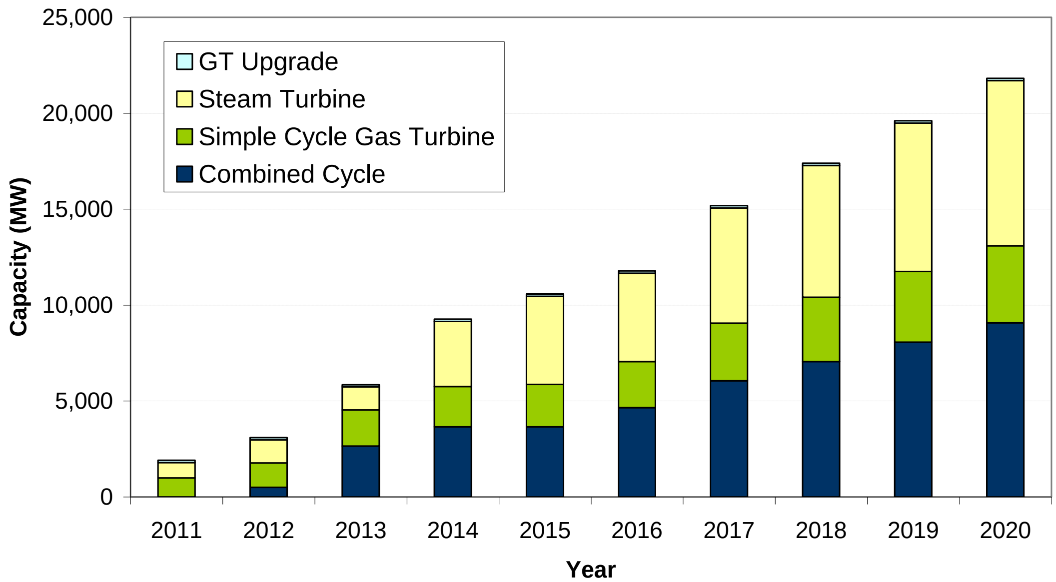


Figure 5-6: Number of Days that Must be Impacted to Achieve a 5 Percent Peak Reduction

5.3. THE VALUE OF A FIVE PERCENT PEAK REDUCTION

A five percent reduction in the system peak could produce significant benefits in the KSA. Most significantly, the reduction in peak demand could avoid the need to build 1,900 MW of peak generating capacity.[69] The capacity expansion plan for the KSA over the next 10 years suggests that nearly this amount of capacity will be added in 2011, and that almost 22,000 MW of capacity will be added by 2020.[70] Over 4,000 MW of this capacity is peaking units that will be utilized during relatively few hours of the year and could be avoided through peak reductions. Figure 5-7 summarizes the capacity expansion plan.



Source: IPA Energy + Water Economics, Volume II - Capex and Opex Review, prepared for ECRA, August 2010
Note: Values for 2018 through 2020 are a linear extrapolation based on average annual growth from 2011 to 2017

Figure 5-7: Projection of Cumulative Future SEC Capacity Additions

A five percent reduction in the system peak would also likely lead to the deferral of certain new transmission and distribution expansion projects. Additionally, to some extent, the reduced usage during peak hours would avoid some energy cost (even if that consumption was shifted to lower-priced off-peak hours).).[71] In total, over a 10 year time horizon and assuming a discount rate of 10 percent, the total gross benefit of a five percent peak reduction in the KSA could be SR 3.8 billion. Figure 5-8 illustrates the breakdown of energy, T&D capacity, and generating capacity benefits.

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[69] This is a conservative assumption, because it assumes that the avoided capacity is equal to the reduced peak load and does not gross up for potential line losses and reserve margin requirements.

[70] IPA Energy + Water Economics, *Volume II - Capex and Opex Review*, prepared for ECRA, August 2010. Values for 2018 through 2020 are a linear extrapolation based on average annual growth from 2011 to 2017.

[71] Additionally, to the extent that LM/DR measures are automated and able to provide fast-response load reductions, spinning reserve value (or other ancillary services) could enhance the benefits estimate.

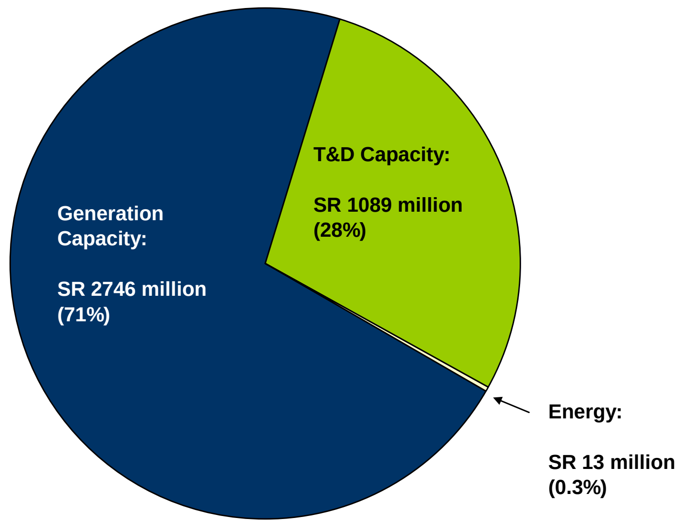

Figure 5-8: Avoided Costs Attributable to 5% System Peak Reduction (10 year NPV)

In conversations with stakeholders, some suggested that this gross benefits estimate of SR 3.8 billion (or roughly SR 600 million per year) seemed small relative to the total projected infrastructure investment of SR 20 to 40 billion per year. However, it is important to note that benefits of this magnitude are being achieved through load curtailments during a very small number of hours in the year. If the LM/DR programs were dispatched on 20 days for a period of four hours each time, that would mean that the load curtailments are used in less than one percent of the hours of the year. Through load curtailments during this small number of hours, up to three percent of the total infrastructure investment is being avoided.

5.4. Implications for LM/DR Strategy

This analysis has several implications for the target level of LM/DR impacts that may be appropriate for the KSA and design characteristics of future LM/DR programs that are offered.

LM/DR is a viable option for achieving a moderate (e.g., five percent) reduction in peak demand at the system level in the KSA. At the regional level, a five percent (or more) reduction is feasible for the Eastern, Western, and—most likely—Central regions. The flatter load shape of the Southern region requires a different approach.

To achieve a five percent reduction in the system peak, it may be necessary to establish a portfolio of LM/DR programs that is larger than this amount. This is due to the operational limitations of LM/DR measures. For example, there is some uncertainty in the ability to forecast the timing of the system peak and call a LM/DR event at that exact time. Also, any single LM/DR measure will likely have a cap on the number of events that can be called, creating further challenges related to dispatching the LM/DR event during a peak hour. Creating an "oversized" LM/DR portfolio will help to address these issues and increase the likelihood that the target peak reduction will be achieved.

To achieve a system peak reduction between five and ten percent, a combination of DR, EE, and PLS programs will be needed. Common examples of EE measures that could contribute to peak impacts such as these include air-conditioning efficiency standards and efficient lighting programs. PLS programs such as TOU rates are also commonly used for addressing peak demand issues.

Some general guidelines for effective LM/DR programs also became clear. LM/DR programs should be designed to focus on the summer season, since the highest load hours almost always occur during the period from June through September. Additionally, Saudi DR programs will require a greater number of critical events than are needed in other parts of the world. For example, across regions of the U.S., fewer than 15 critical event days are typically needed (10 is common). In the Kingdom, more critical day events will likely be needed to achieve significant impacts.

It should be noted that a much different conclusion is reached for the Marafiq service territory. Marafiq had a load factor of 88% in 2010. The load shape is very flat due to the very large share of large industrial load in the region. To achieve a five percent reduction in peak demand, the utility would need to call at least 95 LM/DR events over a seven month period. Therefore, LM/DR programs do not appear to be the most attractive option for addressing growth in Marafiq's peak demand. Energy efficiency programs are likely to be a more effective approach. Chapter 7 includes discussion of energy efficiency measures that are good options for the KSA.

Further analysis of historical load data could enhance the value of this analysis. In particular, there appears to be some year-to-year variation in the results. With more years of hourly load data, yearly variation could be examined more closely. Since 2007 and 2009 produced somewhat different results, it would be useful to observe which is more representative of system conditions.

A five percent reduction in peak load could produce significant financial benefits for the KSA, particularly in terms of avoided or deferred generation and T&D capacity. Potential gross benefits of 3.8 billion over a 10 year period suggest that LM/DR programs are a significant untapped resource in Saudi Arabia. Thus, identifying the programs that can most cost-effectively be used to achieve these impacts is an important next step. That is the topic of the next chapter of this report.

6. THE DSM MEASURES

Our analysis assesses the potential for a wide range of demand-side measures to reduce peak demand in the KSA. The primary focus of the analysis is on measures that specifically target consumption reductions during peak hours of the day. However, the analysis also includes an assessment of EE measures – those measures that are designed to reduce overall energy consumption, but without specific requirements about what time of day those consumption reductions occur. In this chapter, we provide descriptions of each of the measures and the characteristics that distinguish them.

6.1. CHARACTERISTICS OF LM/DR OPTIONS

LM/DR measures vary across multiple dimensions. A utility that is implementing a demand response program must make a choice for each of these options before deployment.

1. Customer segment: residential, commercial, industrial, government
2. Signal to the end-use customer: incentive-based or price-based
3. Trigger for the demand response event: reliability vs. price
4. Response requirement: mandatory vs. voluntary
5. Dispatchability: dispatchable vs. non-dispatchable
6. Notification: day-ahead vs. day-of notification
7. Control: utility-controlled vs. customer-controlled
8. Type of incentive payment: fixed vs. "market-based"

Each of these characteristics is described in more detail below.

Customer segment

Due to the different characteristics of each customer segment, demand response measures are created to target each separately, or even to target specific sub-groups within the segments. Because the focus of LM/DR programs is specifically on reducing the system peak demand, customers can be grouped by the size of their individual peak demand. Enrollment in demand response programs would then be limited to customers who meet the peak demand size criteria.

Signal to the end-use customer

Incentive-based options pay customers to reduce load during events called by the program sponsor. These events can be triggered by an emergency on the grid or by high electricity prices. Incentive-based options include programs such as direct load control, interruptible tariffs, and other curtailable load management programs. Price-based options incorporate time varying rates that reflect the cost of providing electricity during different time periods. These rates encourage customers to change consumption patterns and provide opportunities for electricity bill savings. Price-based options include critical peak pricing, peak time rebates, and real-time pricing

Trigger for the demand response event

Demand response events can be either reliability- or price-triggered. Reliability-triggered options are called in response to emergency conditions on the grid (e.g., outages). These options typically provide short notification time due to unpredictable nature of emergencies. On the other hand, price-triggered options are called in anticipation of high market prices.

A single demand response option can be both reliability- and price-triggered, having a dual character. Usually, incentive-based programs are called at times when the system operator or utility determines that the need for peak load reduction is critical. This can occur either when electricity prices are high or when demand is near the reserve margin and there is an increased risk of grid failure (such as blackouts). This distinction does not define any particular program, but is something that can vary within a program category. It is common for LM/DR programs to be triggered by both price and system emergencies.

Response requirement

LM/DR options with mandatory participation requirements carry a stiff penalty fee for non-compliance. Typically, participation in a capacity-market option is mandatory as the load commitment from the end-use customer represents a firm resource level for the utility or program provider.

Voluntary options provide participants an incentive to reduce demand but do not penalize for non-compliance. Participation in dynamic pricing options is usually voluntary. Among incentive-based options, participation in a curtailable load management measure, as well DLC, is typically voluntary.

Alternatively, some LM/DR measures can be offered on a mandatory, voluntary, or "default" basis (with the option to opt-out). While the response requirement for a particular demand response option can be mandatory, participation in the demand response option may be voluntary. For example, enrollment in some curtailable load management measures is voluntary, but once enrolled, all participants are required to reduce their load.

Dispatchability

Dispatchability of LM/DR measures refers to the ability to provide a demand response-inducing signal within a limited timeframe of the event commencement. DLC measures, for example, are dispatchable because they are event-based. A TOU rate, on the other hand, is not dispatchable because the peak period is pre-determined. Dispatchability is the primary characteristic that distinguishes DR programs from permanent load shifting (PLS) programs.

Notification

The amount of response time that is provided to the participant is another characteristic of LM/DR measures. Day-ahead LM/DR options are those which require that the customer be notified a day in advance of the critical event. Day-of could mean 6 hours of notification, 1 hour, 15-30 minutes of notice, or even an instantaneous demand reduction. Day-of options become more feasible if end-use customers are equipped with enabling technology, which allows them to automatically respond to demand response signals. Day-of dispatch requires more customer education and management of expectations. Also, participant incentives increase as notification time becomes shorter. Dynamic pricing can be offered as day-of when customers are equipped with enabling technologies. Among reliability-based options, direct load control (DLC) is a day-of option.

Control

LM/DR options can also be distinguished on the basis of whether the load reduction is being controlled by the utility or by the customer. LM/DR measures such as DLC provide the utility with physical control of the customer's air conditioning, hot water heater, or other appliances. In most LM/DR options, the customer physically controls the demand reduction. This often allows for greater flexibility in which end uses or processes are ramped down. However, a hybrid approach of utility- and customer-controlled demand response is possible where the utility initiates the demand response event, which automatically triggers pre-set load shed parameters set by the customer.

Type of incentive payment

There are variations in the type of incentive payment that is offered to participants in a LM/DR measure. Some options have a fixed level of incentive payment that is not directly tied to electricity market fluctuations in price. For example, DLC participants are usually offered a fixed monthly incentive per kW of load reduction. However, many of the curtailable load management measures provide incentives that are based on fluctuations in the marginal price of energy, capacity, or both.

Depending on how a given LM/DR measure is structured along these characteristics, it will span a spectrum of value to the utility and convenience to the customer. This spectrum, and where each of the characteristics falls on the spectrum, is illustrated in Figure 6-1.

Figure 6-1: Utility Value/Customer Convenience Spectrum

6.2. DEFINITIONS OF THE LM/DR MEASURES

A wide range of LM/DR measures were considered for this project. To avoid potentially excluding a valuable option for the KSA, we started with the broadest possible list of LM/DR measures. The scope of our analysis was not limited to DR programs that are focused on event-based peak reductions. We also included permanent load shifting programs that target reductions during peak hours on most days of the year, as well as information measures that encourage overall conservation by providing customers with more information about their energy usage. These measures are each described in detail below.

Three types of LM/DR programs that have been in place for many years and have an established history of full-scale deployment are direct load control, interruptible tariffs, and curtailable load management.

Direct load control (DLC)

Under direct load control (DLC), a utility or system operator remotely shuts down or cycles a customer's electrical equipment on short notice to address system or local reliability contingencies. In exchange, the customer receives an incentive payment or bill credit. Operation of DLC typically occurs during times of high peak demand. However, it can also be operated when economic to avoid high on-peak electricity purchases.

The traditional DLC measure is implemented as follows. During a DR event, DLC participants have their appliances turned off for the full duration of an event or for various fractions of an hour (e.g., a common duty cycle is 15 or 30 minutes off during an hour). A one-way remote switch is connected to the condensing unit of an air conditioner or to the immersion element in a water heater. The operation of the switch is controlled through radio signals (for older systems) or through digital paging (for newer systems). Most switches also contain multiple relays so that air conditioners and water heaters can be controlled by the same switch with independent control strategies for each relay. Our analysis considers direct control of central air-conditioning systems, as this is how most of the current programs are designed. However, given the high saturation of split-system and window air-conditioning units in the KSA, for future consideration it may be possible to design a program that is applied to the A/C circuit of the home in order to penetrate this larger potential market of participants.

Interruptible Tariff

This measure offers customers a reduced price of electricity in exchange for agreeing to reduce energy demand on short notice (or allow the electric utility to temporarily cut off the energy supply). In the case where the customer has agreed to provide a usage reduction, that reduction must be measured and verified through hourly interval metering data. The measure is typically structured such that customers are reducing usage down to a pre-specified consumption level. This form of demand response is most commonly applied to large commercial and industrial customers. Note that this type of measure must be written into the tariff. Customers are often paid to be "on call" even if a load reduction is not needed. An interruptible rate is also commonly referred to as a curtailable rate.

Curtailable load management (CLM)

CLM is much like an interruptible tariff, except that it is an independently run measure that does not require a change to the tariff language. CLM measures also tend to have more variation in the way incentives are structured. Payments can be made to customers only for unit reductions in usage during event periods (as determined relative to an estimated baseline consumption level), or they can be structured as monthly participation payments regardless of whether DR events are needed. Another feature of CLM programs is that are sometimes structured with voluntary load reductions, for which customers are paid only if they provide the reduction, but not penalized if they do not provide a reduction. This type of arrangement makes the potential impact less reliable from a system operation perspective, but is often more attractive to customers.

For residential, commercial, and government customers, our analysis considers peak time rebates (PTR) to be the form of CLM that is modeled. PTR provides customers with a payment for each kilowatt-hour of consumption that they reduce below an estimated baseline level. This is becoming a common program to offer to customers in the United States among utilities deploying AMI, because in the short-run no customers are made worse off (in the absence of a usage reduction, customers simply pay the existing rate). However, there are challenges associated with establishing the baseline usage level independently for each customer.

Dynamic pricing

There are several dynamic pricing options that can be offered to customers as LM/DR measures. These options convey price signals that incentivize more economically efficient consumption of electricity. These rate designs can include critical peak pricing (CPP), real-time pricing (RTP), and other forms that vary in terms of the granularity of the time-varying price signal. For our analysis, we have used CPP as the relevant rate design.

A CPP measure is an overlay on either time-of-use or flat pricing that uses a predefined critical-peak price that approaches real-time prices at times of the system peak. During these times, the rate is much higher than a normal peak price (e.g., 3x to 5x times the on-peak rate of a TOU). CPP days are dispatched on relatively short notice as needed, for a limited number of days during the year. Usually their timing is known a day in advance of being called.

CPP events can be called during times of system contingencies or when faced with marginal energy costs. These rates are most commonly offered to commercial and industrial customers, but are also being piloted in many cases for residential customers. CPP participants pay a lower off-peak price on all days than they would pay otherwise on their applicable tariff.

Several recent dynamic pricing experiments have shown that customers will curtail a significant amount of load during high-priced peak periods. Actions range from increasing the setpoint on an air-conditioning unit to being more conscious about turning off lights in unoccupied rooms. A list of actions that customers claim to have taken in these pricing pilots is provided in Appendix D.

Demand Subscription Service (DSS)

Another pricing option is demand subscription service. This is similar to dynamic pricing, but allows the customer to manage the amount of price variation to which they want to be exposed. Customers are allowed to buy a baseline amount of energy at a fixed price. The rest of their consumption is exposed to the time-varying prices in the dynamic rate.

Dynamic pricing with advanced DLC

Enabling technologies such as programmable communicating thermostats (PCTs) and automated demand response (Auto-DR), with customer-programmed automated response options, allow automatic responses to critical peak prices.

AutoDR refers to demand response that does not involve human intervention. The load reduction is initiated at a home, building, or facility through receipt of an external communications signal from the utility. The external signal starts pre-determined load reduction strategies that are programmed into the energy management control system or programmable logic controller at the site. AutoDR has received much attention during the past several years, and enabling technologies for fully-automated demand response are expected to be the focus of future developments in this field.

A PCT is a programmable thermostat that can receive information wirelessly from the utility. For customers that participate in a demand response program, the PCT allows the utility to control the thermostat's operation (e.g. set-point temperature, etc.) during demand response events and/or emergency events to avoid blackouts. Some models also display real-time curtailment notifications and price alerts so customers can see when demand response events and peak energy rates are in effect.

Our analysis has also included permanent load shifting (PLS) measures. PLS measures encourage load to be shifted from peak to off-peak hours during most days of the year rather than during a limited number of DR events. These include TOU pricing and behind-the-meter energy storage options.

Time-of-use (TOU) rate

Another form of pricing considered, which is not "dynamic" but is still time-varying, is the TOU rate. A TOU rate divides the day into time periods and provides a schedule of rates for each period. For example, a peak period might be defined as the period from 12 pm to 6 pm on weekdays, with the remaining hours being off-peak. Compared to the flat rate, the TOU rate is higher during the peak period and lower during the off-peak, mirroring the variation in the cost of supply. There is certainty as to what the prices are during each period and when each period will occur. This rate is currently offered to large C&I customers in the KSA, but for the purposes of our analysis was considered for the other customer segments as well.

Thermal energy storage (TES)

Generally defined, TES systems allow the user to shift consumption away from peak periods by providing a storage medium (water or ice) that acts as a heat sink for the rejection of heat from loads. The storage medium is then recharged (ice is refrozen or water is rechilled) during the off-peak period. Large systems apply to central chiller systems commonly found in large office buildings, many government buildings, centralized shopping malls, large hotels, and hospitals. Smaller systems are packaged HVAC rooftop units which are more common for small retail buildings (e.g. box stores), small offices, mosques, government buildings, and smaller hotels.

In addition to PLS, our LM/DR analysis also includes information measures. These are measures that, by providing customers with new information about their energy consumption patterns, encourage peak reductions or overall conservation. In-home information displays, web portals, and social norming are all measures under consideration.

In-home information display (IHD)

An IHD is a device that provides utility customers with a prompt and convenient feedback on their energy consumption. Devices may also display the cost of energy, and estimates of greenhouse gas emissions. The IHD can receive energy consumption data by communicating with the home's smart meter (via cable, power line communications, or radio frequency) or via another energy measurement system.

Web portals

Web portals are a form of internet-based IHD which allow the user to view real-time consumption on any device that can connect to the Internet. Web portals can help to reduce household energy consumption because they provide real-time feedback to homeowners, and homeowners can respond to the information by changing their energy consumption behavior. Many utilities are developing web portals as part of their AMI rollouts, and Google has developed its PowerMeter application to provide similar functionality. A snapshot of the Google PowerMeter is shown in Figure 6-2.

Figure 6-2: Snapshot of Google PowerMeter

Social Norming

Social norming is a very new application in the electricity sector. The concept is that customers' energy use is compared to that of similarly situated neighbors. By showing customers that a percentage of their neighbors are more efficient consumers of electricity, it motivates the participants to use less energy and "compete" with their neighbors. This approach is currently being used in North America by OPOWER, which has achieved overall reductions in usage of around two percent among participating utilities.

6.3. Other LM/DR Measures for Consideration

There are additional LM/DR measures for which the impacts were not quantified in this analysis. However, these are still measures that could be considered for future deployment in the KSA. Impacts of these measures were not quantified for any of the following reasons:

- There is little empirical evidence from other regions upon which to base the analysis, or insufficient in-field deployment experience
- The measures involve technologies that are still early in development, with very few instances of cost-effective deployment
- The measures would be so specific to the Saudi system that extrapolation of case studies from other regions is not applicable

Water pumping demand response

Water management and its challenges within Saudi Arabia makes it very unique compared to any other country in the world. In addition, the electricity requirements for pumping this water across the Kingdom, from desalination plants located on coastal cities to cities within the Kingdom, such as Riyadh, is immense.

For example, the Saline Water Conversion Corporation's (SWCC) Al Jubail Desalination and Power Plant, located on the eastern coast of Saudi Arabia, provides 85% of the water for Riyadh. The water pumping electric load to move the water from Al Jubail to Riyadh is 300 MW alone.[72] In addition, there are several other major desalination plants located on the Western coast which also pump water to other cities in the KSA. From a LM/DR perspective, this large concentrated load could have significant potential if it can be curtailed during peak times.

In California, the Department of Water Resources (DWR) has entered into such an agreement with Pacific Gas & Electric (PG&E).[73] DWR operates an electricity-intensive system that pumps water from the northern part of the state (where it is supplied by runoff from the Sierra Nevada mountain range) to the southern part of the state (where it is needed to serve residents in the highly populated metropolitan areas of Los Angeles and San Diego). By curtailing pumping load during peak times, DWR provides 200 MW of capacity relief to PG&E. The agreement

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[72] Saline Water Conversion Corporation Interview, 13 Dec 2010

[73] The program is called the California Power Authority – Demand Reserves Partnership (CPA-DRP) and was initiated in 2007. The program is only utilized during years when there is not a water shortage. For more information see https://www.pge.com/.../DemandResponse2009-2011-Projects_Other-Doc_PGE_20090325-07.doc.

includes a number of requirements for both parties. For example, PG&E can only call events between 11 am and 7 pm, and DWR is charged a penalty if they provide less than 50 percent of the scheduled load reduction during an event (providing between 50 percent and 100 percent results in a reduced payment).

Behind-the-meter storage

There is a wide range of behind-the-meter storage options. Battery storage is being given significant attention in smart grid deployments due to its scalability and performance characteristics. While the technology is still developing and the economics are largely unproven for most applications today, there is potential for significant longer-term technological cost improvements.

Demand charges

Demand charges are very commonly used in rate design for large industrial and commercial customers in many other parts of the world. Demand charges can be structured in various ways, but generally they impose a per-kilowatt charge on a customer's highest observed demand during peak hours in each month. This provides customers with an incentive to control their consumption during peak times.

Seasonal rates

Given the significant seasonal differences in electricity consumption in the KSA, seasonal rates may be a good option for reducing overall consumption during higher-priced summer months. A brief analysis of the KSA's marginal energy costs suggests that a price differential of more than 50 percent could be justified between the winter and summer seasons. This is an option that can be implemented immediately with the existing electromechanical meters, and would not depend on an upgrade to smart meters.

6.4. Definitions of the EE Measures

The first step of the energy efficiency measure analysis is to identify the list of all relevant EE measures that could be considered as part of the EE potential assessment. EE measures, or efficient energy-consuming equipment, save energy by providing the same service with a lower energy requirement. An example of an EE measure is the replacement of a standard efficiency refrigerator with a high efficiency model.[74] For most EE measures, reference or baseline efficiency levels are estimated as representing the beginning point to determining savings. The savings are based on the efficiency level of the highest efficient product commercially available in the KSA market.

[74] In the US, high efficiency refrigerators are typically referred to as "Energy Star" refrigerators. Energy Star is a US-government program aimed at setting minimum efficiency standards for manufacturers of appliances and other energy-using products to adhere to. To our knowledge, Energy Star is not branded for these products in KSA.

Several sources of information were consulted to develop the list for this study, including the review of previous studies and reports on EE completed for KSA over the past several years, combined with our knowledge and experience of EE measures from having conducted similar studies over the past three decades. Because of this experience, there are literally hundreds of EE measures to choose from. Many of these measures are not necessarily suitable to the conditions in the KSA. To help narrow the list of possibilities down to just those measures that are suitable and applicable for implementation given the conditions in the Kingdom, we conducted a qualitative screen. The qualitative screen identifies a set of criteria that best defines each measure's applicability to the various consumer bases in the KSA. Representative screening criteria included:

- **Technological Maturity:** Is the measure commercially available and supported by the necessary market infrastructure? Or, will the technology and any required support industry be commercially available within the defined energy efficiency assessment horizon?
- **Good Match:** Is the measure applicable to the climate, building stock, or equipment that is typical in the KSA?
- **Best Measure Available:** Is there a similar measure that addresses a specific inefficiency in equipment, operation, or building envelope that is clearly superior in performance, acceptability to consumers, commercial availability, and cost-effectiveness?
- **Quantified Savings:** Can the costs and impacts of the measure be quantified such that an economic evaluation is both possible and reasonable? Are the potential savings reasonably large enough relative to the cost to justify a program?
- **Acceptable to Consumers:** Does the measure reduce the quality of energy-service equipment to the point that energy consumers are unwilling to install it in important markets? Is it culturally acceptable in the KSA?
- **Implementable:** Can the measure be implemented in the KSA, given the skills and capabilities required?
- **Regulatory Issues:** Can regulations and/or incentive structures be put in place?

The qualitative screen was meant to guide the subsequent program design efforts and is not meant to be a "concrete boundary" where measures that pass must be included in future programs or where measures that "fail" by this analysis cannot be considered in future programs. There may be instances where a measure fails a qualitative or economic screen but it makes sense to include it in the program. For example, in one recent program design effort we found that although a certain traffic signal color failed the screen because costs were considered excessively high, it was going to cost the city much more to replace that light color separately. In this instance, it was obvious that the "failed" measure needed to be included for the program to work, and the overall program remained cost-effective.

The sections that follow identify the EE measures that were selected for further assessment in this study. Each section corresponds to each of the four market sectors that are being studied: residential, commercial, government, and industrial. Detailed descriptions of the measures are provided in Appendix E.

6.3.1. Residential EE Measures

The residential measures span all end uses and vary significantly in the manner in which they impact energy consumption. Table 6-1 presents a summary of the measures, which focus predominantly on cooling, lighting, and appliances.

Table 6-1: Summary of Residential EE Measures

Cooling	Lighting
Central AC Split System AC Room AC Programmable Thermostat	Compact Fluorescent Lamps Thin Tube Lamps and Electronic Ballasts LED Lamps
Building Envelope	**Appliances**
Insulation (ceiling and wall) High Efficiency Windows Windows, Shading	Clothes Washer Dishwasher Refrigerators and Freezers
Water Heating	**Other**
High Efficiency Water Heaters	Home Electronics - Televisions, computers, etc.

6.3.2. Commercial EE Measures

The EE measures for the commercial sector span a variety of end uses and vary significantly in the manner in which they impact energy consumption. Table 6-2 presents a summary of the measures.

Table 6-2: Summary of Commercial EE Measures

Cooling	Lighting
High Efficiency Split System AC High Efficiency Packaged AC High Efficiency Chiller Systems District Cooling Systems Variable Speed Chiller Systems Cooling Tower, High-Efficiency Fans Condenser Water, Temperature Reset Economizer, Installation Fans, Energy-Efficient Motors Fans, Variable Speed Control HVAC Retrocommissioning Pumps, High-Efficiency Motor Pumps, Variable Speed Control Thermostat, Clock/Programmable	Compact Fluorescent Lamps Fluorescent, High Bay Fixtures Thin Tube Lamps and Electronic Ballasts LED Lamps LED Exit Lighting Occupancy Sensors High-Pressure Sodium Lamps Metal Halide Lighting
Refrigeration	**Building Shell**
Compressor, High-efficiency Compressor, Variable-speed Demand Defrost Controls, Anti-Sweat Heater Controls, Floating Head Pressure Evaporator Fan Controls Strip Curtains	Insulation-Ceiling Insulation-Ducting Insulation-Radiant Barrier Insulation-Wall Cavity Roofs- High Reflectivity Windows- High Efficiency
Other	
Office Electronics - Monitor, Copier/Printer, etc. Vending Machine, High Efficiency	

6.3.3. Government EE Measures

The EE measures for the government sector span a variety of end uses and building types and vary significantly in the manner in which they impact energy consumption. Table 6-3 presents a summary of the measures.

Table 6-3: Summary of Government EE Measures

Cooling	Lighting
High Efficiency Split System AC High Efficiency Packaged AC High Efficiency Chiller Systems District Cooling Systems Variable Speed Chiller Systems Cooling Tower, High-Efficiency Fans Condenser Water, Temperature Reset Economizer, Installation Fans, Energy-Efficient Motors Fans, Variable Speed Control HVAC Retrocommissioning Pumps, High-Efficiency Motor Pumps, Variable Speed Control Thermostat, Clock/Programmable	Compact Fluorescent Lamps Fluorescent, High Bay Fixtures Thin Tube Lamps and Electronic Ballasts LED lamps LED Exit Lighting Occupancy Sensors High-Pressure Sodium Lamps Metal Halide Lighting Municipal Streetlighting
Other	
Municipal Pumping	

6.3.4. Industrial EE Measures

Because of the wide diversity of applications in the industrial sector, it is nearly impossible to articulate all of the possible energy-efficiency measures that would be applicable to each application. However, most if not all of these applications contain motors at their core. As such, we look primarily at high efficiency motors as a measure category. There are many variations of high efficiency motors (e.g., high efficiency, premium efficiency, etc.). Each variation is being addressed across all of the industries represented in the KSA.

7. ASSESSING THE MEASURES

Each of the previously described measures is unique in terms of their system impacts, costs, benefits, and applicability in the KSA. Certain measures will be economically attractive options. Others will not be a good fit. In some instances, measures may not be economically attractive options in the short run, but have the potential to become attractive in the long term as system conditions change, technology costs decrease, and customers become more educated about their demand-side options. The purpose of this chapter is to provide an assessment of the relative economic attractiveness and potential size of each measure. This analysis ultimately contributes the selection of the best measures for the KSA and provides insight for grouping them into programs.

We take a two-step approach to our analysis. The first step is to assemble the best available information on each measure to develop an "economic screening curve." This curve provides insight about the relative economic attractiveness of each of the measures, as well as some idea about which measures will be cost-effective and which will not. The second step is to estimate the potential size of each measure in terms of peak load reductions and overall energy savings. The combination of these two analyses – economic attractiveness and resource size – is then used to draw insights about which measures to consider for deployment in the KSA. Figure 7-1 illustrates, at a high level, this approach.

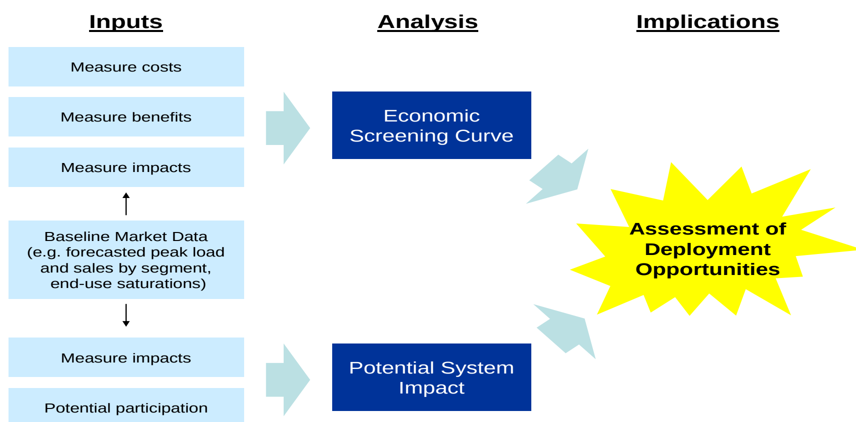

Figure 7-1: Approach to Measure Analysis

There is an important point to make about the conclusions that can be drawn from this approach. The cost-effectiveness assessment for individual measures is broadly conducted for each of four customer segments: residential, commercial, industrial, and government. The analysis is restricted to these segments due to data limitations. As a result, our analysis is conducted using the characteristics of the *average* customer in each segment. In reality, there are *sub-groups* of customers within these segments for which conclusions of the economic screening assessment may differ from what is concluded for the segment on average. Therefore, the results are more useful for thinking about the advantages and disadvantages of the individual measures at a high level than for drawing definitive conclusions about which specific measures to pursue. Analysis at a greater level of segmentation will be a necessary component of implementation activities. To address the uncertainty that is inherent in many of the important observations in this analysis, we have conducted a sensitivity analysis. These results are summarized in Appendix F.

Our analysis is presented separately for LM/DR measures and for EE measures. This chapter first presents our analysis of the LM/DR measures, and then the EE measures.

7.1. Assessing the LM/DR Measures

7.1.1. LM/DR Screening Approach and Assumptions

As described in previous chapters of this report, the LM/DR analysis takes a very broad perspective on the measures that are considered, to avoid excluding any potentially attractive options for the KSA. The 30 measures that were evaluated are illustrated in Figure 7-2.

Category	Option	Res	Comm	Ind	Govt
DR	DLC (traditional)	×	×		×
DR	Adv. DLC (PCT, Auto-DR) + price signal	×	×	×	×
DR	Interruptible Tariff		×	×	×
DR	Curtailable load management (incl. PTR)	×	×	×	×
DR	Dynamic pricing (e.g. CPP, RTP)	×	×	×	×
DR	Demand subscription service	×	×	×	×
PLS	TOU	×	×		×
PLS	Thermal energy storage		×		×
Info	In-home information displays	×			
Info	Web portals	×			
Info	Social norming (e.g. OPOWER)	×			

Note: "X" indicates that the measure was evaluated, gray shading indicates that it was not.

Figure 7-2: LM/DR Measures Included in Economic Screening Analysis

Certain measures were not evaluated for some customer segments. This is because these measures are not applicable to those segments. For example, no interruptible tariff programs exist for residential customers (but DLC programs are, to some extent, like an interruptible tariff with enabling technology, i.e., direct control of end uses). Energy storage options also are not applicable for residential customers. Information measures, on the other hand, apply only to the residential segment and have not been offered to other customer classes. TOU pricing was not included as a new measure for the industrial segment, because it is already largely being offered to these customers.[75]

To determine each measure's relative economic attractiveness, a benefit-cost ratio is calculated. Calculation of the benefit-cost ratio requires three basic inputs: the per-customer load impact of each measure, the marginal supply-side costs that would be avoided through changes in the load profile, and the per-customer cost of offering each measure. The relationship between these three inputs when calculating the benefit-cost ratio is described in Figure 7-3.

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[75] However, the likely impacts of the industrial TOU rate have been estimated as a point of reference. This estimate is provided later in Chapter 7.

$$\textbf{Benefit-Cost Ratio} = \frac{\textbf{Per-customer impact}\ \text{(kW, kWh)} \times \textbf{Avoided cost}\ \text{(generating capacity, energy, T\&D capacity)}}{\textbf{Per-customer cost of measure}\ \text{(equipment, program admin, import cost on equip)}}$$

Figure 7-3: The Benefit-Cost Ratio Calculation

To illustrate this calculation, consider residential DLC.[76] This measure typically produces a peak reduction of around 1.1 kW per customer in the U.S.[77] However, in Saudi Arabia air conditioners are less efficient and therefore consume more energy. Additionally, houses with central air-conditioning (the focus of most DLC programs) tend to be larger than those in the U.S. Therefore, the peak reduction impact per participant in the KSA is likely to be higher. For this analysis we have scaled the expected impact of the DLC program to reflect the size difference between customers with central air-conditioning in the KSA and the U.S.[78] The result is an expected per-participant load reduction of 2.7 kW in the KSA.

The vast majority of benefits from this measure would be entirely driven by avoided capacity costs, not energy costs, since it is utilized during relatively few hours of the year. The avoided cost per kW-year of generating capacity and T&D capacity is 321 SR/kW-year (236 SR/kW-year + 85 SR/kW-year, respectively). Therefore, the annual gross benefit of this measure is roughly 867 SR/kW-yr (2.7 kW x 321 SR/kW-yr). Assuming a 20 year life of the measure and an annual discount rate of 10%, the present value of the benefit is 7,378 SR.[79]

The per-customer cost of the measure is driven largely by equipment costs (i.e. the cost of the switch that controls the air-conditioning unit). There are also program administration costs and other ongoing program-related costs. Assuming a cost of roughly 750 SR per switch, a 15 percent import cost markup, and a 15 percent markup to account for program administration and other ongoing costs, the total cost of the measure, is 975 SR.[80] The result is a benefit-cost ratio of 7.6 (7,378 SR benefit / 975 SR cost), suggesting that the measure is economically attractive.

This perspective on cost-effectiveness is what is referred to as the Total Resource Cost (TRC) test. The TRC test takes a societal perspective on the costs and benefits of each measure. In other words, it looks at the total collective benefits to the utility and the customer, and compares those to the collective costs. Costs do not include, for example, incentive payments, because

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76 The step-by-step calculations for this measure are provided in Appendix G, along with similar examples for two other LM/DR measures.

77 Based on conversations with utility engineers and a review of survey results from FERC Staff, "2008 Assessment of Demand Response and Advanced Metering," December 2008.

78 See Appendix G for details on how this scaling was performed.

79 20 years is at the upper-end of the range of estimates of the expected life of some technologies, but is an appropriate assumption for utility LM/DR programs.

80 More detail on costs and other assumptions is provided in the sections of Chapter 7 that follow.

they are simply a transfer of wealth from the utility to the customer. This is one of the most commonly used cost-effectiveness tests used by regulators and utilities across the globe.[81]

The inputs to the benefit-cost ratio calculation, therefore, are important assumptions. In our analysis, all inputs were based on the best available data and calibrated whenever possible to reflect Saudi system conditions. Specific assumptions about impacts, costs, and benefits of LM/DR measures are described below.

Per-customer impacts

Generally, per-customer impact assumptions were derived from a survey of dynamic pricing studies and full-scale program deployments across the globe. When the data was available, impacts were tailored to Saudi system conditions using climate data and information about end-use appliance saturations (see Chapter 4 for more information). When faced with a choice between two equally representative assumptions, we chose the more conservative (lower) option to reflect the relatively limited experience with LM/DR measures in the KSA.

Most LM/DR programs produce significant reductions in peak demand, but little or no change in net energy consumption. There are two reasons for this. First, LM/DR programs are typically utilized for a limited number of times per year (typically only around 100 hours). As a result, even if the peak reductions are quite large in the hours for which they are called, they are small relative to total consumption over the course of the entire year. Second, LM/DR programs often reduce consumption during peak hours, but cause an increase in consumption during off-peak hours. As a result, even the small reductions that are realized at peak times are offset by these off-peak increases. Therefore, we have assumed no change in total consumption due to DR programs.

We have also assumed that energy storage measures produce no net change in consumption. In reality, in some instances energy storage can lead to a slight increase in consumption due to inefficiencies in the technology. In other cases, it can produce net energy savings. Ultimately, this effect is very technology specific and it will not substantially alter our findings in either direction.

Information-based measures are the exception and are assumed to produce not only peak demand reductions, but reductions in overall consumption as well. This has been demonstrated through a number of pilots, particularly pertaining to in-home information displays, and some studies on the effects of social norming (i.e., comparison of energy bills across customers to motivate change in behavior by engaging in peer competition among neighbors).[82] For our analysis, we assume that these measures produce the same consumption reduction during peak hours as during off-peak hours (on a percentage basis).

The range of per-customer impacts varies quite significantly across each measure and segment.

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[81] For more information, see CPUC, *The California Standard Practice Manual*, October 2001.

[82] Faruqui, Ahmad, et.al., "The Impact of Informational Feedback on Energy Consumption - A Survey of the Experimental Evidence," Energy, August 2009. Also, Summit Blue Consulting, "Impact Evaluation of OPOWER SMUD Pilot Study," September 2009.

There are a number of reasons for why this is the case:

- On a percentage basis, residential customers tend to be more price responsive than the other segments; therefore, the residential class demonstrates the largest percentage impacts when enrolled in pricing programs (e.g. TOU, CPP, DSS).[83]

- Customer price responsiveness is also driven by climate and end-use saturation; areas with high saturations of central air-conditioning (CAC) or hot weather tend to exhibit higher levels of price responsiveness; the relatively low CAC saturation in the KSA among residential customers dampens their responsiveness.[84]

- Measure impacts vary depending on whether load curtailments are voluntary or mandatory (with penalties for non-compliance); those programs with mandatory load reductions, such as interruptible tariffs, produce larger impacts than those with voluntary reductions, like PTR

- Measures with a lower frequency of DR events tend to produce large impacts when the events are utilized; this is particularly true of the reported impacts for CLM and interruptible tariff measures

- Measures also tend to produce larger impacts if they involve a control technology that will automatically reduce load during DR events, or generally during peak periods; this is true of DLC measures and energy storage measures

- Measures that only provide information without a monetary incentive to reduce consumption tend to produce lower impacts on average

Estimates of customer price responsiveness (i.e. price elasticity) were developed for the KSA by calibrating the results of dynamic pricing pilots that have been conducted around the world to Saudi system conditions. This is done using the Price Impact Simulation Model (PRISM), which has formed the basis for the United States Federal Energy Regulatory Commission's (FERC's) National Assessment of Demand Response Potential and many utility DR program assessments.[85] The model uses information about climate, end-use saturations, rates, and other variables to produce two different types of elasticity estimates that ultimately determine the assumed level of price responsiveness in each segment. Additional details about the PRISM tool are provided in Appendix H.[86]

In addition to using the calibrated PRISM tool, representative impact assumptions for the KSA were drawn from a survey of LM/DR program deployments around the world. The impacts are a composite of these results and are summarized in Table 7-1. They are represented as a

83 Faruqui, Ahmad, Ryan Hledik, and John Tsoukalis, "The Power of Dynamic Pricing," The Electricity Journal, April 2009.

84 Charles River Associates, Impact Evaluation of the California Statewide Pricing Pilot, Final Report. March 16, 2005. Customers with CAC have more discretionary load and therefore a greater ability to respond during DR events.

85 The FERC Assessment can be found at: http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf

86 The PRISM tool is available at http://www.edisonfoundation.net/iee/databases/index.htm.

percentage reduction in the average customer's baseline peak demand, as characterized in Chapter 4.

Table 7-1: LM/DR Per-customer Impact Assumptions (% Reduction in Customer Coincident Peak Load)

Segment	LM/DR Measure	Impact	Source	References
Res	DLC (traditional)	22%	Based on review of U.S. DLC program impacts and scaled to account for larger average size of KSA customers with central A/C; impact is shown as percent of peak for those large customers	
Res	Adv. DLC + price signal (PCT, Auto-DR)	12%	Based on review of dynamic pricing and technology pilots, the incremental impact of a PCT for residential customers is a 75% increase over the impact from dynamic pricing alone	[1]
Res	Curtailable load management (incl. PTR)	11%	PTR impact is assumed to be 2/3 of dynamic pricing impact, based on observations from recent pricing pilots	[2], [3]
Res	Dynamic pricing (e.g. CPP, RTP)	16%	Based on PRISM simulation of residential customer price responsiveness in areas with hot and dry climate but fairly low saturation of central A/C; assumes 8-to-1 peak-to-off-peak price ratio	[4]
Res	Demand subscription service	11%	DSS is an innovative way to package a dynamic rate and allow customers to manage risk - therefore, the impacts are assumed to be the same as those from PTR	
Res	TOU	10%	Based on PRISM simulation of customer price responsiveness in areas with hot and dry climate but fairly low saturation of central A/C; assumes 4-to-1 peak-to-off-peak price ratio	[4]
Res	In-home information displays	7%	Best estimate based on survey of international pilots to test the impact of various forms of informational feedback; usage reduction applies to all hours, not just peak	[5], [6]
Res	Web portals	0.5%	General utility assumption in AMI business cases; usage reduction applies to all hours, not just peak; very limited empirical evidence is available for this measure	
Res	Social norming (e.g. OPOWER)	3%	Reported average impacts of OPOWER; accounts for a 2% system wide impact that is provided by 80% of customers who are "aware" (i.e. participating) of the social norming information; impact applies to all hours	[7]
Comm	DLC (traditional)	41%	Assumes the per-kW impact is twice as large as residential due to greater A/C load; this was the assumption used for small commercial customers in the FERC Assessment of DR Potential	[8]
Comm	Adv. DLC + price signal (PCT, Auto-DR)	5%	Based on review of dynamic pricing and technology pilots, the incremental impact of a PCT for commercial customers is a 100% increase over the impact from dynamic pricing alone	[9]
Comm	Interruptible Tariff	45%	Based on review of impacts from states with interruptible tariff programs; adjusted downward to account for issue that these programs are very rarely utilized and therefore achieve impacts that are larger than expected if the programs were used more frequently	[10]
Comm	Curtailable load management (incl. PTR)	3%	PTR impact is assumed to be 2/3 of dynamic pricing impact, based on observations from recent pricing pilots	[2], [3]
Comm	Dynamic pricing (e.g. CPP, RTP)	5%	Based on PRISM simulation of small/medium (<200 kW) C&I price responsiveness; assumes 8-to-1 peak-to-off-peak price ratio	[4]
Comm	Demand subscription service	3%	DSS is an innovative way to package a dynamic rate and allow customers to manage risk - therefore, the impacts are assumed to be the same as those from PTR	
Comm	TOU	3%	Based on PRISM simulation of small/medim C&I price responsiveness in areas with hot and dry climate; assumes 4-to-1 peak-to-off-peak price ratio	[4]
Comm	Thermal energy storage	34%	Assumes that 60% of air conditioning load can be shifted to off-peak; based on assumptions in recent California report on permanent load shifting potential	[11]
Ind	Adv. DLC + price signal (PCT, Auto-DR)	10%	Based on review of dynamic pricing and technology pilots, the incremental impact of Auto-DR is a 100% increase over the impact from dynamic pricing alone	[1]
Ind	Interruptible Tariff	45%	Based on review of impacts from states with interruptible tariff programs; adjusted downward to account for issue that these programs are very rarely utilized and therefore achieve impacts that are larger than expected if the programs were used more frequently	[10]
Ind	Curtailable load management (incl. PTR)	45%	Based on review of impacts from states with interruptible tariff programs; adjusted downward to account for issue that these programs are very rarely utilized and therefore achieve impacts that are larger than expected if the programs were used more frequently	[10]
Ind	Dynamic pricing (e.g. CPP, RTP)	10%	Based on PRISM simulation of large C&I (>200 kW) price responsiveness; assumes 8-to-1 peak-to-off-peak price ratio	[4], [12]
Ind	Demand subscription service	7%	DSS is an innovative way to package a dynamic rate and allow customers to manage risk - therefore, the impacts are assumed to be the same as those from PTR	
Govt	All measures	N/A	Assumed equal to commercial impacts; little empirical evidence is available to refine this assumption	

References

[1] Charles River Associates, Impact Evaluation of the California Statewide Pricing Pilot, Final Report. March 16, 2005
[2] Northeast Utilities, "Results of CL&P Plan-it Wise Energy Pilot," Docket No. 05-10-03RE01.
[3] eMeter, "PowerCentsDC Program Final Report," prepared for the Smart Meter Pilot Program, Inc., September 2010.
[4] Faruqui, Ahmad, Ryan Hledik, and John Tsoukalis, "The Power of Dynamic Pricing," The Electricity Journal, April 2009.
[5] Faruqui, Ahmad, et.al., "The Impact of Informational Feedback on Energy Consumption - A Survey of the Experimental Evidence," Energy, August 2009.
[6] Darby, Sarah, "The Effectiveness of Feedback on Energy Consumption," prepared for the Environmental Change Institute at the University of Oxford, April 2006.
[7] Summit Blue Consulting, "Impact Evaluation of OPOWER SMUD Pilot Study," September 2009.
[8] FERC, "A National Assessment of Demand Response Potential," prepared by The Brattle Group, Freeman, Sullivan & Co., and Global Energy Partners, June 2009.
[9] Wikler, G., et. al., "Enhancing Price Response through Auto-DR," Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings, August 2008.
[10] FERC Staff, "2008 Assessment of Demand Response and Advanced Metering," December 2008.
[11] Energy & Environmental Economics, "Statewide Joint IOU Study of Permanent Load Shifting," November 2010.
[12] Goldman, Charles, et al, "Estimating Demand Response Market Potential Among Large Commercial and Industrial Customers: A Scoping Study," LBNL, January 2007.

Per-customer measure costs

Costs of implementing each measure were developed on a per-customer basis. The general approach was to first identify any equipment or technology costs that may be required by the measure (including installation costs). These cost estimates are generally based on a review of utility regulatory filings, business cases, and conversations with industry professionals and suppliers with expertise on these issues.

Then, any equipment costs were increased using a 15 percent adder to reflect import costs to the KSA, since they presumably would not be produced domestically. Finally, to account for remaining program costs, such as program development, administration, and other fixed and recurring costs, an additional adder of between 5 and 15 percent was used. The lower adder was used for measures with high potential participation rates, since the fixed costs would presumably be spread across a larger number of participants. The higher adder was used for measures with lower potential participation.

Examples of equipment costs included in the analysis are AMI (for pricing measures), air-conditioning switches, programmable communicating thermostats (PCTs), in-home information displays, Auto-DR systems, and thermal energy storage units.[87] These equipment costs are based on observations from utilities that have offered programs at a similar size and scale to those that will likely be offered in the KSA. For measures without an equipment cost, such as web portals and social norming, cost estimates included IT systems costs and ongoing mailing and support. Cost assumptions for the industrial segment tend to be conservative (i.e. on the high side) and include the cost of metering where it would be necessary for verifying the impacts of the LM/DR measure. However, it should be noted that this conservative assumption does not affect the conclusions as all industrial measures are found to be cost-effective (discussed in detail later in this chapter). Cost assumptions are summarized in Table 7-2.

[87] AMI costs are net of the operational benefits (e.g. avoided meter reading costs). In order to achieve these benefits, AMI must be deployed to all customers, rather than just selectively deploying it to small pockets of customers.

Table 7-2: LM/DR Per-customer Measure Cost Assumptions

Segment	LM/DR Measure	Cost (SR)	Source	References
Res	DLC (traditional)	975	SR 750 equipment (A/C switch) cost + 15% program admin + 15% import cost	[1]
Res	Adv. DLC + price signal (PCT, Auto-DR)	975	SR 750 PCT cost + 15% program admin + 15% import cost	[1], [2]
Res	Curtailable load management (incl. PTR)	1,219	SR 938 AMI cost + 15% program admin + 15% import cost	[2]
Res	Dynamic pricing (e.g. CPP, RTP)	1,219	SR 938 AMI cost + 15% program admin + 15% import cost	[2]
Res	Demand subscription service	1,219	SR 938 AMI cost + 15% program admin + 15% import cost	[2]
Res	TOU	1,219	SR 938 AMI cost + 15% program admin + 15% import cost	[2]
Res	In-home information displays	488	SR 375 IHD cost + 15% program admin + 15% import cost	[3]
Res	Web portals	65	SR 56 IT cost + 5% program admin	[4]
Res	Social norming (e.g. OPOWER)	197	SR 188 internet and mailing cost + 5% program admin (little empirical evidence for this measure)	[5]
Comm	DLC (traditional)	1,706	SR 1,312 A/C switch cost + 15% program admin + 15% import cost	[1]
Comm	Adv. DLC + price signal (PCT, Auto-DR)	1,706	SR 1,312 PCT cost + 15% program admin + 15% import cost	[1], [2]
Comm	Interruptible Tariff	1,219	SR 938 AMI cost + 15% program admin + 15% import cost	[2]
Comm	Curtailable load management (incl. PTR)	1,125	SR 938 AMI cost + 5% program admin + 15% import cost	[2]
Comm	Dynamic pricing (e.g. CPP, RTP)	1,125	SR 938 AMI cost + 5% program admin + 15% import cost	[2]
Comm	Demand subscription service	1,125	SR 938 AMI cost + 5% program admin + 15% import cost	[2]
Comm	TOU	1,125	SR 938 AMI cost + 5% program admin + 15% import cost	[2]
Comm	Thermal energy storage	18,000	SR 7,500/kW cost of system + 15% program admin + 15% import cost	[6]
Ind	Adv. DLC + price signal (PCT, Auto-DR)	65,813	SR 50,625 cost of Auto-DR system per participant + 15% program admin + 15% import cost	[7]
Ind	Interruptible Tariff	35,000	SR 35,000 per-customer technology , recruitment, and admin cost (estimate from previous project work in the KSA)	
Ind	Curtailable load management (incl. PTR)	35,000	SR 35,000 per-customer technology , recruitment, and admin cost (estimate from previous project work in the KSA)	
Ind	Dynamic pricing (e.g. CPP, RTP)	35,000	SR 35,000 per-customer technology , recruitment, and admin cost (estimate from previous project work in the KSA)	
Ind	Demand subscription service	35,000	SR 35,000 per-customer technology , recruitment, and admin cost (estimate from previous project work in the KSA)	
Govt	All measures	N/A	Equal to commercial costs scaled proportionally by customer size (ratio of avg government customer's peak to average commercial customer's peak)	

References

[1] Based on conversations with researchers at the California Public Interest Energy Research Program
[2] Based on review of net AMI costs in multiple utility business case filings. Assumption used in FERC's 2009 *A National Assessment of Demand Response Potential* .
[3] Primen, Inc., "California Information Display Pilot Technology Assessment, Final Report," December 21, 2004.
[4] Derived from 2009 BGE AMI business case: APPLICATION OF BALTIMORE GAS AND ELECTRIC COMPANY FOR AUTHORIZATION TO DEPLOY A SMART GRID INITIATIVE AND TO ESTABLISH A TRACKER MECHANISM FOR THE RECOVERY OF COSTS, filed July 2009
[5] General estimate based on industry experience
[6] Low-end cost of equipment as identified in a conversation with a manufacturer of TES systems in Saudi Arabia.
[7] Average based on project team's experience implementing Auto-DR programs for U.S. utilities

Avoided Costs

The basis for our avoided cost estimates is documented in detail in Chapter 5 of this report; they are summarized below in Table 7-3.

Table 7-3: KSA Avoided Cost Estimates

Avoided Capacity	(SR/kW-yr)
Generation	236
T&D	85
Avoided Energy	**(SR/MWh)**
Summer Peak	60
Summer Off-Peak	50
Winter Peak	40
Winter Off-Peak	35

For DR measures, it is assumed that only capacity costs will be avoided through peak reductions, and energy costs will remain largely unchanged.[88] For TOU pricing and energy storage measures, we assume that the same amount of load that is discharged during the peak period will be consumed during the off-peak period. In this case, while there is no net change in consumption, there is a reduction in energy costs due to the energy arbitrage value of the. These PLS measures also provide avoided capacity benefits through the reduction in consumption during the peak. Information measures are assumed to provide year-round energy cost reductions as well as capacity cost reductions as a result of the flat impact profile described earlier in this section.

7.1.2. The LM/DR Economic Screen

The three inputs (impact, cost, and benefit) are combined to produce a benefit-cost ratio for each individual measure. The result is an "economic screening curve" that provides information regarding the relative economic attractiveness of each of these measures. In some cases, measures have very high benefit-cost ratios that are much in excess of 4-to-1. In other cases, measures are slightly above or below a ratio of 1-to-1. Other measures have costs that significantly outweigh the benefits and are well below a ratio of 0.5-to-1. The LM/DR economic screening curve is presented in Figure 7-4.

88 In the longer-term, it may also be possible to use LM/DR programs to provide ancillary services. Utilizing LM/DR to provide near-instantaneous load reductions is seen in very limited instances among utilities with significant sophistication and experience with LM/DR.

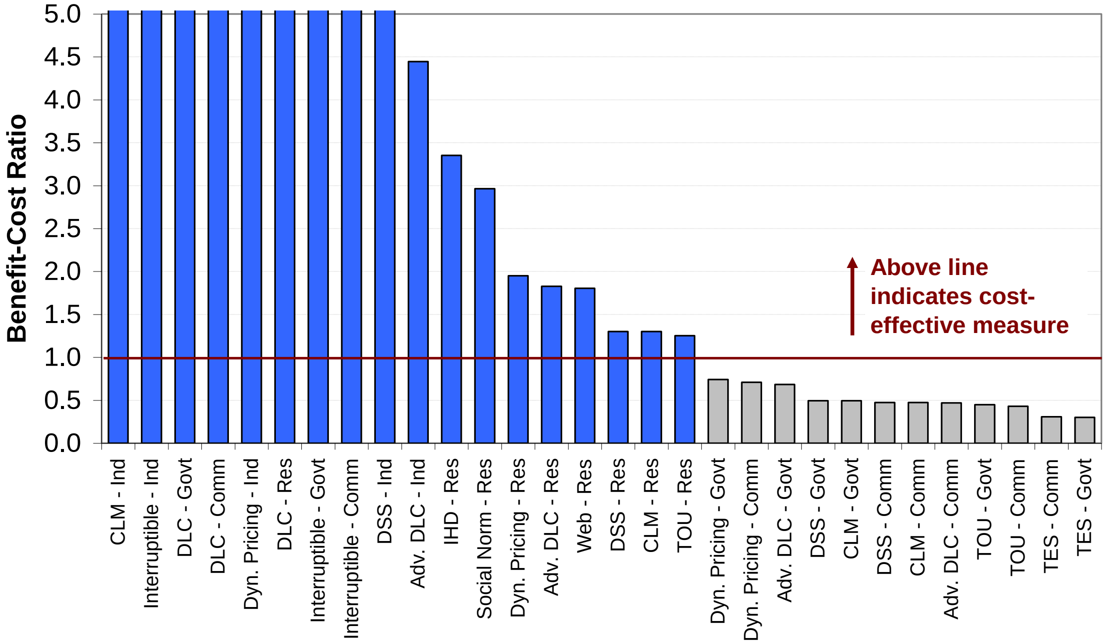

Figure 7-4: The LM/DR Economic Screening Curve

Some of the most economically attractive LM/DR measures for the KSA, based on this screen, are interruptible tariffs for all eligible (non-residential) customer segments, as well as curtailable load management for the industrial segment. The reason for this is that these programs historically have tended to produce very large impacts among participants. In fact, many programs report 100 percent load curtailment among participants, suggesting that the enrolled participants simply shut down their operations during the critical event. Utilities operating these programs have not typically utilized them very often, so participants are not forced to take these measures on a regular basis. Knowing this, they enroll at the maximum level of load curtailment in order to receive the full participation incentive. These programs also produce significant impacts because they often include non-compliance penalties. If the programs were utilized more regularly, the expected impacts (and therefore benefits) would likely be smaller.[89] However, even if that were the case, a sensitivity analysis that reduces the assumed peak reduction from these programs by half still finds that they are some of the most cost-effective measures analyzed.

DLC measures are another economically attractive set of options for the KSA. These measures have the advantage of being fairly low-cost and reliable, with significant impacts being driven by the high share of air-conditioning load in Saudi Arabia's peak demand. Conventional DLC is cost-effective for all eligible segments, and advanced DLC (using Auto-DR or PCT technology along with a dynamic pricing signal) is attractive for the industrial and residential segments since these customers generally tend to be more price responsive than the commercial and government segments.

[89] To reflect the likely impact of more frequent use of these programs in the KSA, we have derated the reported impacts from 90% to 45%.

Among residential customers, information measures present some level of economic attractiveness. These are fairly low cost options, but can only provide the most valuable information if they are being fed interval data from smart meters. If these measures are offered in the absence of smart meters, customers mostly only have access to monthly billing data and develop less of an understanding of their energy consumption behavior. As a result, the impacts may be lower in the absence of AMI. It is also important to note that there is less information available about the potential impacts and costs of these types of measures, since they are relatively new options being tested by utilities.

Time-based pricing could be an attractive option for residential and industrial customers. For these segments, the cost of AMI is offset by the benefits of peak demand reductions, as exhibited by the benefit-cost ratio that exceeds 1.0. It is important to note that, to ultimately capture the full benefits of AMI, smart meters must be deployed to all customers rather than just to specific sub-segments of customers. For example, meter reading costs can only be avoided through full-scale deployment of smart meters. If it is the case that AMI is deployed across the country on this basis, then it could make sense to offer dynamic rates to all customers, including the less price sensitive classes like commercial and government, since the incremental cost of offering these rates would be minimal.

Pricing options such as DSS, PTR, and TOU tend to produce smaller impacts than CPP rates. With these options, customers are exposed to less risk if they do not reduce peak load. In the case of the TOU, this is because the peak price signal is lower. For the PTR, studies have found that given a rebate that is equivalent in magnitude to the critical peak price of a CPP rate, customers are less responsive. And with DSS, customers would presumably, on average, purchase part of their baseline consumption at a fixed rate and therefore expose less of their consumption to price volatility. In all cases, creating stronger price signals, or offering these measures in combination with other LM/DR programs, could improve the cost-effectiveness and result in a more economically attractive option. These possibilities will be explored further in the implementation stages when programs (groups of measures) are being developed.

Contrary to popular perception, thermal energy storage is the least economically attractive option for the KSA in this analysis. The reason is that the high technology cost of these measures significantly outweighs the benefits, producing a benefit-cost ratio around 0.3. In other parts of the world, TES has been found to be cost-effective for specific applications. There are a number of reasons why this differs from our finding for the KSA:

- The marginal cost of energy is artificially low in the KSA due to the 10- to 15-fold discount at which SEC buys fuel oil from Saudi Aramco (a price of $5/bbl versus a world market price of $75/bbl). As a result, the peak-to-off-peak price differential is very small and the energy arbitrage value of storage, which could be quite significant in other parts of the world, is insignificant in the KSA.[90]

- Our approach to quantifying the benefits of each measure does not include some benefits that might make these measures cost-effective for certain sub-groups of customers. For

[90] The measures can also be evaluated against an unsubsidized energy price. This is discussed further later in this chapter.

example, in new construction TES could allow the owners of new buildings to invest in a smaller air-conditioning system (fewer chillers) and would reduce the rooftop space requirement of the system. It may also allow for a smaller network connection.

- The economic attractiveness of thermal energy storage options will be specific to the size of the individual customer. Larger customers would be candidates for large central systems (e.g. 300 tons or greater) while small commercial customers would find smaller packaged units (e.g. 25 to 50 tons) to be the more economically attractive option.

- Energy storage projects in other regions are not always pursued purely on the merits of cost-effectiveness. For example, many such projects in California are pursued as technology demonstrations, or to encourage the development of a market for a technology which, over the longer term, could experience significant cost reductions and become economically attractive.

The implications of these findings will be discussed later in this chapter.

7.1.3. Potential LM/DR Measure Impacts

Cost-effectiveness is not the only criterion for determining the best LM/DR measures to pursue in the KSA. Another important question is the potential size of the measures. In the aggregate, after accounting for feasible levels of customer participation, will the measure produce large or small reductions in the system peak? A given measure may be highly cost-effective, but if the associated reduction in aggregate peak demand is very small, then it may be of less interest and should be given lower priority in the KSA's demand response plan. To calculate the potential size of each measure, we multiply the average per-customer impact of the measure by an estimate of the number of eligible customers who would potentially participate (enroll) in the measure. This is summarized in Figure 7-5.

Market Potential of Measure (kW)	**=**	**Per-customer impact** (kW, kWh)	**X**	**Eligible population** (% of entire segment)	**X**	**Achievable participation** (% of eligible customers)

Figure 7-5: The Market Potential Impact Calculation

"Market potential" represents the peak impact of the measure assuming the highest feasible estimate of customer participation based on global best practices. For example, participation in dynamic pricing for non-residential customers is assumed to be based on a default (i.e. "opt-out") rate offering. However, a default dynamic pricing rate offering is not a feasible assumption for the residential class in the KSA, as it would be too significant of a departure from the current approach to rate-setting for this class. Alternatively, the participation rate for this segment is derived from the highest achieved voluntary participation in time-based pricing programs. Electricity de France (EdF) has achieved an enrollment rate of 38 percent in its TOU rate among residential customers. Utilities in the U.S. (Arizona) have achieved similar levels of participation.[91] However, given the low level of energy awareness among residential customers in the KSA (perhaps largely attributable to the artificially low electricity rates) we have cut this estimate in half, resulting in a 19 percent residential dynamic pricing participation rate.

Participation assumptions for each measure are derived from best practices achievements in other regions of the world. In a sense, this provides an upper-bound estimate on the level of impacts that might be realized by offering each measure. Of course, as system conditions deviate from our baseline projections, this potential estimate could change as well. However, given known conditions and the data that is available, an upper-bound is essentially what is represented by the market potential estimate.

It is important to note that market potential is estimated independently for each measure. Thus, the potential impacts are not necessarily additive across measures. When simultaneously offering multiple measures to a given customer segment, there may be "cannibalization" of impacts to some extent. There may be limitations on the number of programs in which customers can enroll. Further, if dual enrollment is allowed, the impacts of one measure could reduce the amount of peak load that is available to be reduced through other measures.[92] Program-level potential estimates that account for these effects will be developed in the implementation stages of this project.

For pricing measures, potential participation is a very under-researched area. This is because pricing measures (with the exception of TOU pricing) are relatively new, particularly for non-industrial customers, and experience with full-scale deployments is limited. However there has been some research conducted on customer preferences for dynamic pricing through various pilots, and this information is the basis for a 75 percent participation assumption associated with a default rate offering for non-residential customers.[93] In other words, this information suggests that, when customers are automatically enrolled in a time-based rate with the option to revert back to their old (flat) rate, only 25 percent will revert back to the flat rate. On the other hand, the voluntary (opt-in) participation rate for residential customers, as described earlier, is 19 percent. This is the percent of customers assumed to actively enroll in a time-based rate when provided with that option.

Participation rates for measures with a longer established history – such as CLM, interruptible tariffs, and direct load control – are based on a review of reported participation rates from utilities that have deployed these programs on a full-scale basis. To capture the full potential participation that may be achievable in the KSA, we have generally chosen the 75th percentile of the distribution of these participation estimates as a feasible assumption, and have reduced that

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91 Based on conversations with rates managers at EdF, Arizona Public Service, and Salt River Project.

92 For example, consider a situation where both a TOU rate and a DLC program are offered. If a customer is enrolled in both, the peak reduction that is attributable to the TOU rate would need to be incremental to that of the DLC rate. In other words, it would only reflect additional actions taken in response to the rate, beyond the air-conditioning load reduction that is caused by the DLC program.

93 Momentum Market Intelligence. Customer Preferences Market Research: A Market Assessment of Time Differentiated Rates Among Residential Customers in California. December 2003.

estimate in cases where the KSA is likely to achieve lower enrollment in the short- or medium-term.[94] The assumed participation rates for each measure are provided in Table 7-4.

Table 7-4: LM/DR Potential Participation Estimates (% of Customers in Segment)

Segment	LM/DR Measure	Eligible (% of segment)	Participating (% of eligible)	Total Particip. (% of segment)	Source	References
Res	DLC (traditional)	5%	20%	1%	20% participation among eligible customers (those with central air conditioning), based on best practices from a review of utility DLC participation estimates (provided via email)	[1]
Res	Adv. DLC + price signal (PCT, Auto-DR)	5%	20%	1%	20% participation among eligible customers (those with central air conditioning)	[1]
Res	Curtailable load management (incl. PTR)	100%	17%	17%	Assumes voluntary (opt-in) residential rate offering; based on vontary TOU enrollment rates in France and the U.S. (Arizona), and derated by 50% to represent lower energy awareness in KSA	[2]
Res	Dynamic pricing (e.g. CPP, RTP)	100%	17%	17%	Assumes voluntary (opt-in) residential rate offering; based on vontary TOU enrollment rates in France and the U.S. (Arizona), and derated by 50% to represent lower energy awareness in KSA	[2]
Res	Demand subscription service	100%	17%	17%	Assumes voluntary (opt-in) residential rate offering; based on vontary TOU enrollment rates in France and the U.S. (Arizona), and derated by 50% to represent lower energy awareness in KSA	[2]
Res	TOU	100%	17%	17%	Assumes voluntary (opt-in) residential rate offering; based on vontary TOU enrollment rates in France and the U.S. (Arizona), and derated by 50% to represent lower energy awareness in KSA	[2]
Res	In-home information displays	100%	20%	20%	Assumes opt-in adoption rate of the technology similar to that of DLC technology; little empirical evidence is available in this area	[2]
Res	Web portals	30%	75%	23%	Of the share of the Saudi Arabian population with internet access (30% according to World Bank), assumes 75% participation	[3]
Res	Social norming (e.g. OPOWER)	100%	80%	80%	Based on OPOWER reported awareness of utility customers	[4]
Comm	DLC (traditional)	90%	10%	9%	10% participation among eligible customers (those with central air conditioning); assumed to be lower for commercial customers than for residential	
Comm	Adv. DLC + price signal (PCT, Auto-DR)	90%	10%	9%	10% participation among eligible customers (those with central air conditioning); assumed to be lower for commercial customers than for residential	
Comm	Interruptible Tariff	100%	5%	5%	75th percentile participation for medium C&I (<200 kW) customers in US among distribution of state-level participation estimates	[5]
Comm	Curtailable load management (incl. PTR)	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Comm	Dynamic pricing (e.g. CPP, RTP)	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Comm	Demand subscription service	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Comm	TOU	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Comm	Thermal energy storage	33%	100%	33%	Assumes 33% of buildings would have physical room for thermal energy storage system, and that 100% of eligible buildings participate (i.e. TES adoption is mandated for eligible buildings)	[7]
Ind	Adv. DLC + price signal (PCT, Auto-DR)	90%	20%	18%	20% participation among eligible customers (those eligible for Auto-DR)	[2]
Ind	Interruptible Tariff	100%	25%	25%	75th percentile participation for medium C&I (<200 kW) customers in US among distribution of state-level participation estimates	[5]
Ind	Curtailable load management (incl. PTR)	100%	20%	20%	75th percentile participation for medium C&I (<200 kW) customers in US among distribution of state-level participation estimates	[5]
Ind	Dynamic pricing (e.g. CPP, RTP)	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Ind	Demand subscription service	100%	75%	75%	Assumes default (opt-out) rate offering; based on best available research from pricing pilots	[6]
Govt	All measures	N/A	N/A	N/A	Assumed equal to commercial impacts; little empirical evidence is available to refine this assumption	

References

[1] Based on best practices from a review of utility DLC participation estimates (provided via email)
[2] Based on conversations with rates managers at Electricite de France, Arizona Public Service, and Salt River Project
[3] BGE and Pepco utility business case assumptions, but requires further empirical analysis upon full deployment
[4] Summit Blue Consulting, "Impact Evaluation of OPOWER SMUD Pilot Study," September 2009.
[5] FERC Staff, "2008 Assessment of Demand Response and Advanced Metering," December 2008.
[6] Momentum Market Intelligence. Customer Preferences Market Research: A Market Assessment of Time Differentiated Rates Among Residential Customers in California. December 2003.
[7] Average eligibility rate based on project team's experience with TES programs for U.S. utilities

For each measure, regardless of cost effectiveness, the total participation rate is multiplied into the average peak reduction per-customer to arrive at an estimate of the total system-level impact that could potentially be realized by offering the measure through a full-scale deployment. The results of this analysis are illustrated in Figure 7-6. These impacts assuming full participation was reached in 2012, to give an idea of how the market potential roughly compares to current peak conditions. In reality, it would take time to ramp up to full participation – realistic ramping rates are presented in Chapter 12 of this report.

94 The distribution is based on state-wide averages of LM/DR enrollment rates calculated from FERC's 2008 survey of U.S. utilities. FERC Staff, "2008 Assessment of Demand Response and Advanced Metering," December 2008.

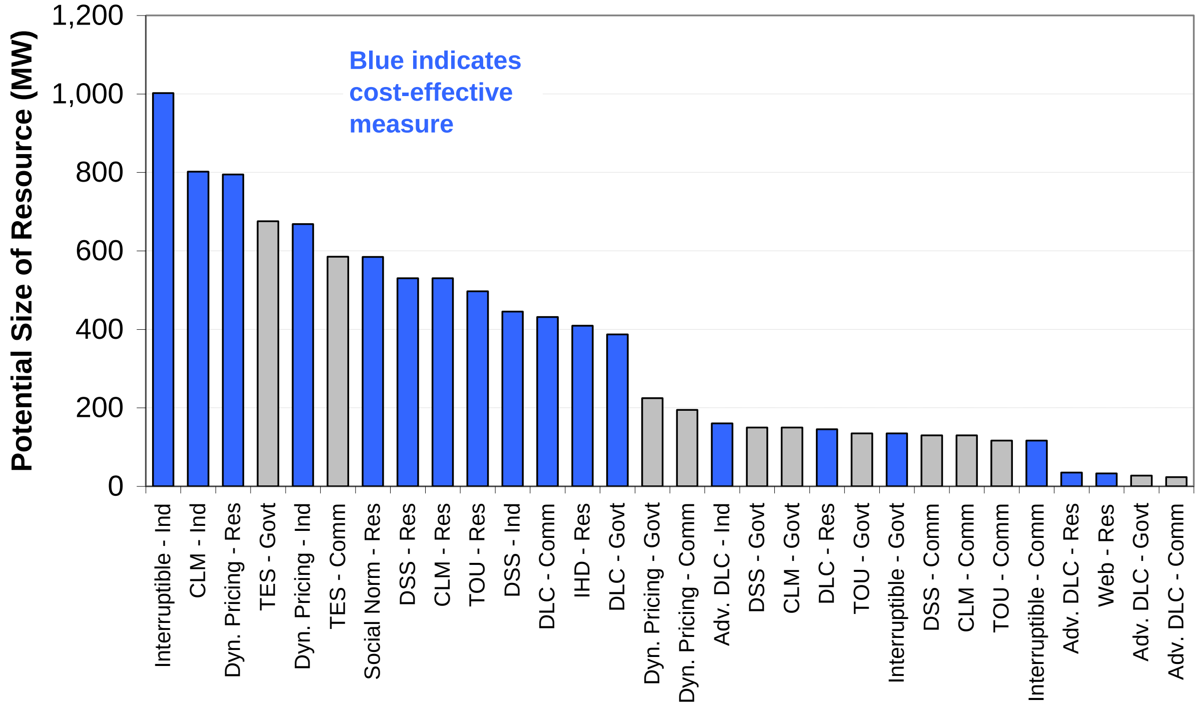

Figure 7-6: Potential Size of LM/DR Measures (2012)

The measures with the largest potential which are also cost-effective are industrial interruptible tariffs and curtailable load management. Despite somewhat limited levels of enrollment that these measures have seen through large-scale deployments in other regions, the large potential is driven by very large peak reductions that are provided by the participants. Much of this is attributable to the mandatory nature of the load curtailments (i.e. penalties for non-compliance) in the design of these measures.

Another group of cost-effective measures with large potential is residential pricing measures. By far the largest share of peak load resides in the residential segment, and default dynamic pricing is a way to reach the largest number of these customers and produce some of the largest impacts. Other residential pricing options have significant potential for similar reasons. Some of the barriers to offering default dynamic pricing, and possible solutions, are discussed in Chapters 9 and 10 of this report.

Many of the cost-effective measures exhibit moderate levels of potential. DLC and non-industrial interruptible tariffs generally fall into this category. While these programs produce significant impacts on a per-customer basis, historically they have appealed only to a limited subset of customers. For example, DLC programs appeal to customers for whom the sacrifice in comfort and control of their air-conditioner is more than offset by the incentive payment to participate.[95]

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95 Although in some instances, with intelligent A/C cycling strategies, participants in DLC programs are reporting little or no loss of comfort.

As an interesting point of comparison, we also estimated the expected impact of the mandatory industrial TOU rate. This estimation relied on a similar methodology described for the measures above. All industrial customers were assumed to be enrolled in the rate, and representative price elasticity estimates (i.e. estimates of customer price responsiveness) were adopted from other regions using the PRISM model. This resulted in an estimated reduction in peak consumption of approximately 6 percent per customer, assuming a 3-to-1 peak-to-off-peak price ratio in the TOU rate (which is the current design). In the aggregate across all customers, this translates to an estimated peak reduction of 450 MW in 2012.[96] Thus, the industrial TOU rate could be expected to produce a sizeable impact upon full deployment in the KSA.

Measure Potential by Operating Area

Due to differences in the customer mix, peak load, and sales in each operating area, LM/DR measure potential will vary geographically. Figure 7-7 illustrates the allocation of each measure's potential by operating area.

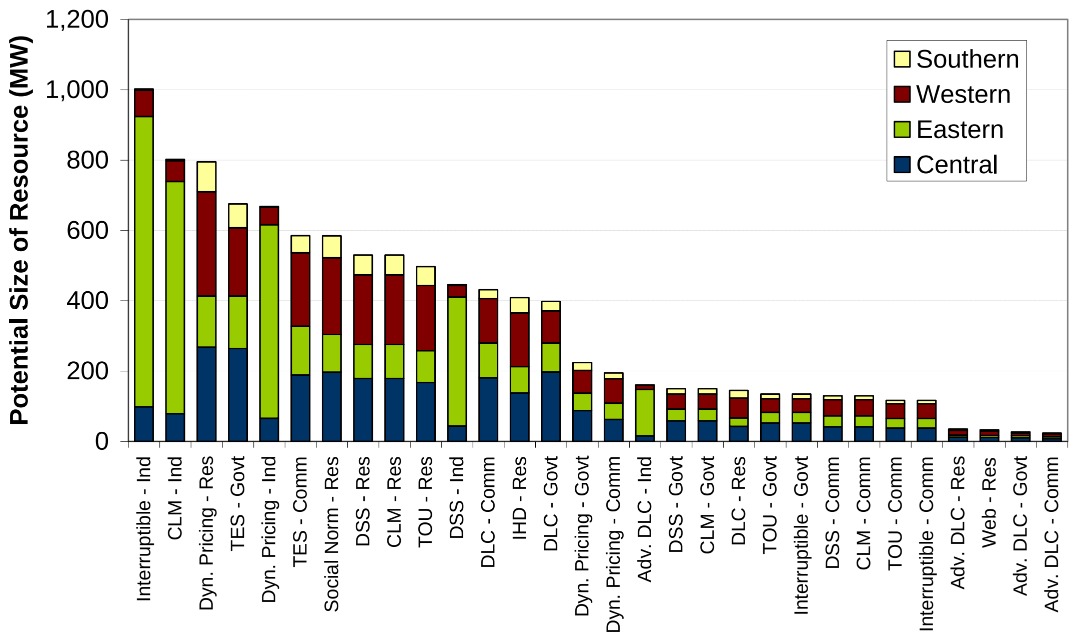

Figure 7-7: LM/DR Measure Potential by Operating Area (2012)

The vast majority of the residential potential is in the Central and Western operating areas, which is where most of the country's residential load is located. Alternatively, industrial measures have the most potential in the Eastern operating area. The Southern operating area has some potential among residential, commercial, and government measures, but due to the low level of industrial load in the region, has little potential for that customer segment.

96 It should be noted that this is lower than the ~565 MW reduction from industrial TOU rates reported by SEC in 2010 (which implies a 6 percent reduction in industrial coincident peak load). Further analysis of the SEC industrial customer load data, controlling for the effect of weather and other variables on consumption, would help to resolve this discrepancy.

Measure Potential by Year

As peak load grows, the potential impact of each measure will grow as well. At the system level, this can be quite significant, with the potential impact of the measures growing by between 10 and 60 percent over the next decade. Figure 7-8 illustrates the increase in measure potential between 2012 and 2021. Specifically, the red bar represents the incremental growth in potential between 2012 and 2016, and the green bar represents the incremental growth in potential between 2016 and 2021. These estimates are driven by population and load growth. Generally, the most LM/DR potential growth is in the industrial and residential segments, where significant load growth is also expected.

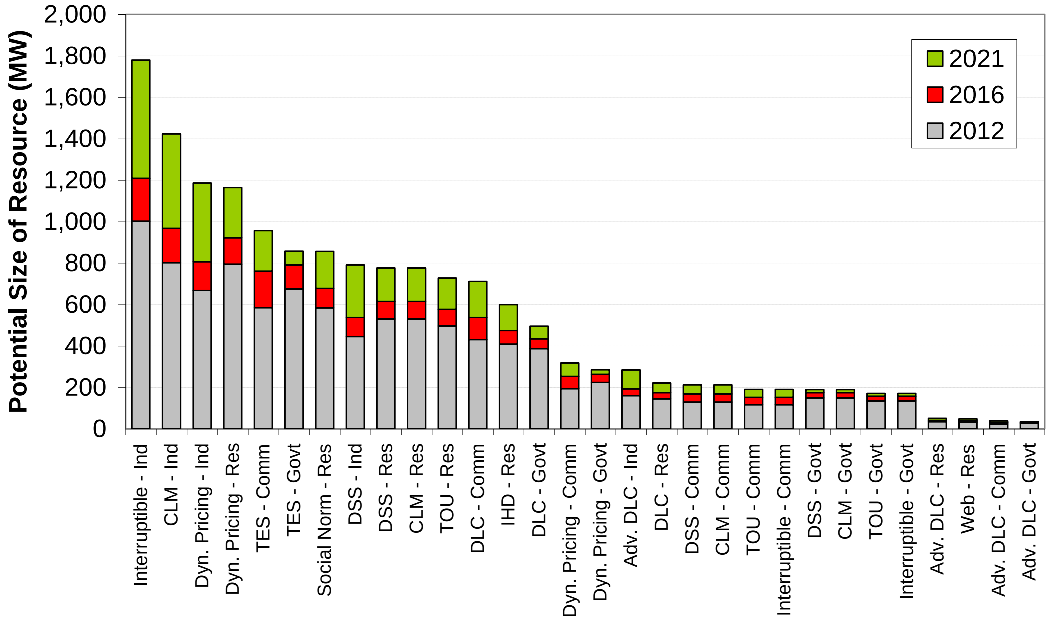

Figure 7-8: LM/DR Measure Potential by Year

7.1.4. LM/DR Implications for the KSA

The results of the economic screening and potential assessments can be combined to inform decisions about how best to pursue LM/DR opportunities in the KSA. Generally, measures with large potential and high benefit-cost ratios tend to be the ideal candidates for LM/DR programs. Measures with little potential that are economically unattractive are less likely to be successful. In Figure 7-9, each measure is characterized according to its potential size and benefit-cost ratio.

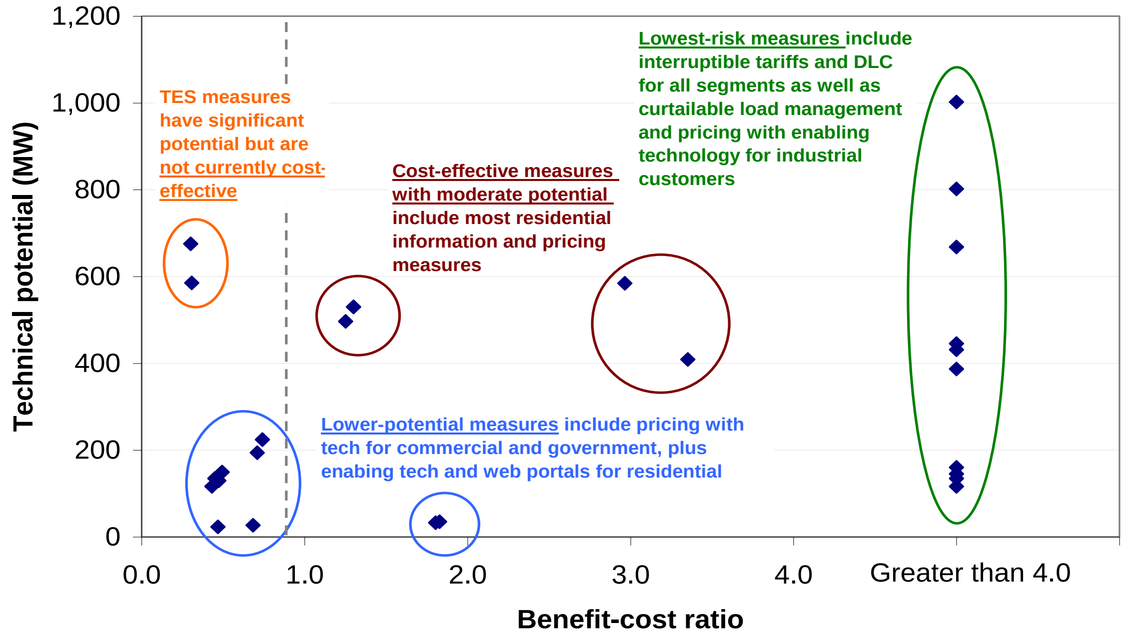

Figure 7-9: Potential Measure Impact and Cost-Benefit Ratio (2012)

Several implications can be drawn from this comparison of LM/DR measures. Interruptible tariffs and direct load control appear to be high-value, low-risk propositions for the KSA. These are globally-tested measures with a long history of proven impacts. This category of measures would also include curtailable load management for large (mostly industrial) customers, which is similar to an interruptible tariff but with differences in the way the participation incentives are structured.

Most residential pricing and information measures also have significant potential and a fairly high likelihood of being cost-effective. This includes dynamic pricing, social norming, in-home displays, and other forms of time-based rate design. It should be noted, however, that due to the more limited global experience with these programs, the impacts and economics are more uncertain. Industrial dynamic pricing with enabling technology would also fall into this category; despite the high benefit-cost ratio, there is some uncertainty around the potential impacts and adoption rates.

Commercial and government pricing and enabling technology measures have lower but significant potential. These may not pass the cost-effectiveness screen as standalone measures, but could prove to be cost-effective when offered as a package in a larger-scale program with other measures (e.g. when sharing the cost of AMI deployment across segments). Web portals and residential enabling technologies also have lower potential, but some degree of economic attractiveness.

Thermal energy storage measures are not broadly cost-effective for any major customer segment. However, for reasons stated earlier, this does not necessarily mean that these measures would not provide a net benefit for certain specific sub-segments of customers. A more detailed market analysis specific to energy storage measures in later stages of LM/DR deployment could help to identify these market segments.

7.2. Assessing the EE Measures

7.2.1. EE Screening Approach and Assumptions

In order to assess the achievable market potential for energy efficiency, it is first necessary to perform an economic screen on each individual measure. The results of the economic screen then serve as the reference point by which market potential is derived. The economic screen applied in this study is a Total Resource Cost (TRC) test that compares the lifetime benefits (both energy and peak demand) of each applicable measure with installed cost (including material, labor and administration of a delivery mechanism, such as an EE program). The lifetime benefits are obtained by multiplying the annual energy and peak demand savings for each measure by all appropriate avoided costs for each year, and discounting the dollar savings to the present value equivalent. In our analysis, we include both energy savings and peak demand savings benefit associated with each energy efficiency measure. The measure savings, costs and lifetimes are obtained as part of the measure characterization. For economic screening of measures, cash incentives that might be paid to the customer to shorten the payback period and make energy investments more appealing are not included in the assessment because they represent a transfer payment from one member of society to another and thus have no effect on the overall measure cost from a societal perspective.

Economic screening was performed for all measures specified in this study. It is important to note the following points about the economic screen:

- The economic evaluation of every measure in the screen is conducted relative to a baseline condition. For instance, in order to determine the kilowatt-hour (kWh) and kW savings potential of a measure, its kWh consumption and demand must be compared to the kWh consumption and demand that would have existed in the absence of the measure, i.e., in the baseline condition.
- The economic screen uses either the full or the incremental cost for each measure. Incremental cost was used for situations in which the decision is between the purchase and installation of a standard efficiency unit and a high-efficiency unit. For instance, the incremental cost of a high efficiency refrigerator is the additional cost of purchasing this unit compared to a comparable unit without the high efficiency rating. Full cost was used for situations in which the measure is added to an existing end-use or process. For example, programmable thermostats are represented as full costs since they are measures that are added to the building in order to enhance and/or improve the cooling energy efficiency.
- The economic screening was conducted only for measures that are applicable to each building type and vintage; thus if a measure is deemed to be irrelevant to a particular building type and vintage, it is excluded from the respective economic screen table.
- In compliance with international best practices involving TRC evaluations, the measure costs were increased by 15 percent to account for administrative costs related to program implementation needed to promote the measure.

Unit Impact and Cost Assumptions for EE Measures

As described earlier, the first step after the qualitative screening process was to characterize all measures in terms of their unit impacts and costs. For each measure, we indicate both energy savings (kWh/unit) as well as demand savings (kW/unit).[97] Tables 7-5 to 7-8 present the characteristics of the measures in terms of their lifetime, unit impacts and costs. For each measure, the tables also indicate the end-use to which a particular measure belongs. Similar to the approach followed for the LM/DR measures, all costs reported in these tables include a 15% premium to reflect import tariffs for all energy efficiency products, which tend to be manufactured by foreign-owned companies.[98]

For the residential sector, the measures are grouped into the following major end-uses: space cooling, building envelope measures such as high efficiency windows and insulation, lighting, water heating, and appliances (see Table 7-5 below).

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97 For studies of this nature, energy savings and peak demand reduction estimates are typically derived for measures by making a series of assumptions about the baseline conditions which would prevail in the absence of the measure. The resulting savings are represented by drawing upon various secondary sources as documented in the following measure-specific tables. These savings are ultimately tailored to conditions in the KSA by making adjustments to reflect the unique conditions in the Kingdom. For example, because of the extreme weather conditions in the summer, savings estimates for weather-sensitive measures (mainly cooling) are drawn from comparable regions where data exist (e.g., the desert environment of the southwestern US). Savings represent the average savings relative to replacements of existing equipment versus equipment installed in newly constructed buildings.

98 The following references were used to develop the equipment and measure costs:

- DEER – California Database for Energy Efficient Resources (publicly-available database produced by the California Energy Commission –insert URL)
- DEEM – Database of Energy Efficiency Measures (proprietary database owned by Global Energy Partners)
- LoadMAP – Energy Efficiency Potential study tool (proprietary database owned by Global Energy Partners)
- RS Means Facilities Maintenance and Repair Cost Data
- RS Means Mechanical Construction Costs
- RS Means Building Construction Cost Data
- Sixth Northwest Conservation and Electric Power Plan, Northwest Power Planning Council, Portland, Oregon (2010)
- US Green Buildings Council — LEED New Construction & Major Renovation (2008)
- RS Means Green Buildings Project Planning & Cost Estimating Second Edition (2008)
- Grainger Catalog Volume 398, (2007-2008)

Table 7-5: Unit Impacts and Costs for Residential Sector EE Measures[99]

End-Use	Energy Efficiency Measure	Unit	Lifetime (years)	Incremental Impacts		% electric savings over baseline	Overall per measure cost (SR/unit)	Type of cost (incremental or full)
				Summer Demand (kW)	Electric Savings (kWh/yr)			
Cooling	Central AC- High Eff.	Air-conditioner	14	1.59	5,564	25%	4,708	Incremental
Cooling	Split AC- High Eff.	Air-conditioner	14	0.78	2,720	25%	2,354	Incremental
Cooling	Room AC- High Eff.	Air-conditioner	14	0.30	1,040	25%	1,348	Incremental
Cooling	Programmable Thermostat	thermostat	13	0.24	838	4%	668	Full
Building	Insulation, Ceiling	ft2 of roof area	50	0.002	6	9%	6	Full
Building	Insulation, Wall Cavity	ft2 of wall area	50	0.0001	0.3	7%	0.03	Full
Building	Windows, High Efficiency	ft2 of window area	25	0.001	4	8%	70	Incremental
Building	Windows, Shading	ft2 of window area	10	0.001	4	10%	49	Full
Lighting	Compact Fluorescent Lamps	lamp	5	0.01	71	67%	25	Full
Lighting	T8 lamps and fixtures	lamp	6	0.002	8	20%	12	Full
Lighting	LED lamps	lamp	10	0.02	95	88%	99	Full
Water Heating	Pipe - Hot Water, Insulation	water heater	15	0.00	128	1%	117	Full
Water Heating	Water Heater, Tank Blanket/Insulation	water heater	15	0.00	206	2%	180	Full
Water Heating	Water Heater - Electric, High-Efficiency	water heater	9	0.00	247	2%	873	Incremental
Appliances	Clothes Washer, High-Efficiency	Appliance	12	0.16	1,064	9%	3,224	Incremental
Appliances	Dishwasher, Higher Efficiency	Appliance	12	0.06	372	3%	496	Incremental
Appliances	Home Office Equipment, Higher Efficiency	home PC	4	0.04	159	1%	46	Incremental
Appliances	Range and Oven - Electric, Higher Efficiency	appliance	18	0.03	129	1%	617	Incremental
Appliances	Refrigerator/Freezer, Higher Efficiency	appliance	14	0.04	185	2%	710	Incremental
Appliances	TVs and Home Electronics, Higher Efficiency	TV	11	0.01	35	0.3%	12	Incremental

Table 7-6 presents similar information for the commercial sector, where measure impacts and costs are indicated as per square feet of building floor area.

[99] Measure-specific lifetimes, demand and energy savings come primarily from the following data sources: DEER, DEEM and LoadMAP. Adjustments are made for weather-sensitive end-uses (cooling, building) to reflect the KSA's hotter climate. Measure costs are derived from a variety of sources listed in Footnote #98. For cooling measures, the EER values in the baseline are 7.96 and in the high efficiency case are 10.6. For building shell measures, the assumed R-values for the ceiling are R-25 and for the wall R-19.

Table 7-6: Unit Impacts and Costs for Commercial Sector EE Measures[100]

End-Use	Energy Efficiency Measure	Unit	Lifetime (years)	Incremental Impacts		% electric savings (over baseline)	Overall per measure cost (SR/unit)	Type of cost (Incremental or Full)
				Summer Demand (kW)	Electric Savings (kWh/yr)			
Cooling	Split AC- High Eff	per total bldg.	14	0.0003	1.84	25%	1.1	Incremental
Cooling	Packaged AC- High Eff	per total bldg.	14	0.0001	0.77	16%	1.3	Incremental
Cooling	Chiller -High Efficiency	per total bldg.	20	0.0001	0.62	13%	1.2	Incremental
Cooling	District Cooling	per total bldg.	20	0.0001	0.62	13%	1.4	Incremental
Cooling	Chiller, VSD	per total bldg.	20	0.0001	0.83	29%	5.6	Incremental
Cooling	Cooling Tower, High-Efficiency	per total bldg.	10	0.00	0.001	0.03%	0.2	Incremental
Cooling	Condenser Water, Temperature	per total bldg.	15	0.00004	0.23	9%	1.1	Incremental
Cooling	Economizer, Installation	per total bldg.	15	0.00000	0.31	9%	0.9	Incremental
Ventilation	Fans, Energy-Efficient Motors	per total bldg.	10	0.00002	0.13	5%	0.7	Incremental
Ventilation	Fans, Variable Speed Control	per total bldg.	10	0.0001	0.39	15%	1.6	Incremental
Cooling	HVAC Retrocommissioning	per total bldg.	4	0.00005	0.30	9%	2.0	Incremental
Cooling	Pumps, Variable Speed Control	per total bldg.	10	0.00000	0.01	1%	2.1	Incremental
Cooling	Thermostat, Clock/Programmable	per total bldg.	11	0.00003	0.17	5%	0.6	Full
Lighting	Compact Fluorescent Lamps	per total bldg.	5	0.00001	0.03	67%	0.02	Full
Lighting	Fluorescent, High Bay Fixtures	per total bldg.	11	0.00001	0.06	4%	3.4	Full
Lighting	T8 lamps and fixtures	per total bldg.	10	0.00003	0.18	10%	3.7	Full
Lighting	LED lamps	per total bldg.	10	0.0002	1.19	88%	14.8	Full
Lighting	LED Exit Lighting	per total bldg.	10	0.00	0.01	94%	0.005	Full
Lighting	Metal Halide Lighting	per total bldg.	10	0.0002	1.12	80%	20.4	Full
Refrigeration	Ref Compressor, High Eff.	per total bldg.	15	0.00001	0.04	7%	1.4	Incremental
Refrigeration	Ref Compressor, Variable Speed	per total bldg.	15	0.00000	0.02	7%	1.4	Incremental
Refrigeration	Ref-Demand Defrost	per total bldg.	15	0.000003	0.02	5%	1.0	Full
Refrigeration	Ref Controls, Anti-Sweat Heater	per total bldg.	15	0.000003	0.02	5%	1.0	Full
Refrigeration	Ref Controls, Floating Head	per total bldg.	15	0.000003	0.02	7%	1.7	Full
Refrigeration	Ref- Evaporator Fan Control	per total bldg.	5	0.000003	0.02	1%	0.2	Full
Refrigeration	Ref- Strip Curtain	per total bldg.	8	0.00001	0.06	4%	0.1	Full
Building shell	Insulation-Ceiling	per total bldg.	20	0.00003	0.16	5%	1.2	Full
Building shell	Insulation-Ducting	per total bldg.	20	0.00003	0.16	5%	2.0	Full
Building shell	Insulation-Radiant Barrier	per total bldg.	20	0.00001	0.05	1%	1.3	Full
Building shell	Insulation-Wall Cavity	per total bldg.	20	0.00003	0.15	5%	2.4	Full
Building shell	Roofs- High Reflectivity	per total bldg.	15	0.00004	0.21	6%	0.4	Incremental
Building shell	Windows- High Efficiency	per total bldg.	20	0.00005	0.25	8%	3.8	Incremental

For the government sector, most of the measures are similar to those considered for the commercial sector. Specifically, for the government sector, measures such as municipal street lighting and municipal pumping are included in the analysis. Table 7-7 presents the measure characteristics for the government sector.

[100] Measure-specific lifetimes, demand and energy savings come primarily from the following data sources: DEER, DEEM and LoadMAP. Adjustments are made for weather-sensitive end-uses (cooling, building) to reflect the KSA's hotter climate. Measure costs are derived from a variety of sources listed in Footnote #98. For cooling measures, the EER values in the baseline range from 7.96 to 8.5 and in the high efficiency cases they range form 10.1 to 10.6. For building shell measures, the assumed R-values for the ceiling are R-25 and for the wall R-19.

Table 7-7: Unit Impacts and Costs for Government Sector EE Measures[101]

End-Use	Energy Efficiency Measure	Unit	Lifetime (years)	Incremental Impacts		% electric savings over baseline	Overall per measure cost (SR/unit)	Type of cost (Incremental or Full)
				Summer Demand (kW)	Electric Savings (kWh/yr)			
Cooling	Split AC- High Eff	per total bldg.	14	0.0003	1.84	25%	1.2	Incremental
Cooling	Packaged AC- High Eff	per total bldg.	14	0.0001	0.77	16%	1.3	Incremental
Cooling	Chiller -High Efficiency	per total bldg.	20	0.0001	0.62	13%	1.3	Incremental
Cooling	District Cooling	per total bldg.	20	0.0001	0.62	13%	1.5	Incremental
Cooling	Chiller, VSD	per total bldg.	20	0.0001	0.83	29%	5.9	Incremental
Cooling	Cooling Tower, High-Efficiency Fans	per total bldg.	10	0.00	0.00	0.03%	0.2	Incremental
Cooling	Condenser Water, Temperature Reset	per total bldg.	15	0.000038	0.23	9%	1.1	Incremental
Cooling	Economizer, Installation	per total bldg.	15	0.00	0.31	9%	0.9	Incremental
Ventilation	Fans, Energy-Efficient Motors	per total bldg.	10	0.000021	0.13	5%	0.7	Incremental
Ventilation	Fans, Variable Speed Control	per total bldg.	10	0.0001	0.39	15%	1.7	Incremental
Cooling	HVAC Retrocommissioning	per total bldg.	4	0.00005	0.30	9%	2.1	Incremental
Cooling	Pumps, Variable Speed Control	per total bldg.	10	0.000001	0.01	1%	2.2	Incremental
Cooling	Thermostat, Clock/Programmable	per total bldg.	11	0.00003	0.17	5%	0.7	Full
Lighting	Compact Fluorescent Lamps	per total bldg.	5	0.00001	0.03	67%	0.02	Full
Lighting	Fluorescent, High Bay Fixtures	per total bldg.	11	0.00001	0.06	4%	3.5	Full
Lighting	T8 lamps and fixtures	per total bldg.	10	0.00003	0.18	10%	3.9	Full
Lighting	LED lamps	per total bldg.	10	0.0002	1.19	88%	15.5	Full
Lighting	LED Exit Lighting	per total bldg.	10	0.000002	0.01	94%	0.005	Full
Lighting	Metal Halide Lighting	per total bldg.	10	0.0002	1.12	80%	21.4	Full
Lighting	Municipal Streetlighting- Metal Halide	per lamp	6	0.1500	657	38%	301.7	Full
Lighting	Municipal Streetlighting- High Pressure	per lamp	6	0.1500	657	43%	150.9	Full
Lighting	Municipal Streetlighting- LEDs	per lamp	20	0.1250	548	39%	2011.4	Full
Other	Municipal Pumping	per HP	20	0.0079	45	2%	50.3	Incremental
Building shell	Insulation-Ceiling	per total bldg.	20	0.00003	0.16	5%	1.2	Full
Building shell	Insulation-Ducting	per total bldg.	20	0.00003	0.16	5%	2.1	Full
Building shell	Insulation-Radiant Barrier	per total bldg.	20	0.00001	0.05	1%	1.3	Full
Building shell	Insulation-Wall Cavity	per total bldg.	20	0.00003	0.15	5%	2.5	Full
Building shell	Roofs- High Reflectivity	per total bldg.	15	0.00004	0.21	6%	0.5	Incremental
Building shell	Windows- High Efficiency	per total bldg.	20	0.00005	0.25	8%	4.0	Incremental

For the industrial sector, motors account for the largest share of energy consumption.[102] The remaining energy consumption is primarily comprised of cooling and lighting. Table 7-8 shows the measure characteristics for the industrial sector.

101 *Ibid.*

102 The NEEP Volume 2A report indicates that motors account for almost 70% of the total industrial energy consumption in KSA. Indeed, our assessment of the baseline conditions (from Chapter 4) reflect that motors and compressed air (which primarily are motors-based) represent roughly 90% of the total electricity consumption for the industrial sector.

Table 7-8: Unit Impacts and Costs for Industrial Sector EE Measures[103]

End-Use	Energy Efficiency Measure	Unit	Lifetime (years)	Incremental Impacts		% electric savings over baseline	Overall per measure cost (SR/unit)	Type of cost (Incremental or Full)
				Summer Demand (kW)	Electric Savings (kWh/yr)			
Cooling	Packaged AC- High Eff.	per total bldg. ft2	14	0.0001	0.77	16%	1.3	Incremental
Cooling	Chiller -High Efficiency	per total bldg. ft2	20	0.0001	0.62	13%	1.3	Incremental
Cooling	Chiller, VSD	per total bldg. ft2	20	0.0001	0.83	29%	7.0	Incremental
Cooling	Cooling Tower, High-Efficiency	per total bldg. ft2	10	0.00	0.001	0.03%	0.2	Incremental
Cooling	Condenser Water, Temperature	per total bldg. ft2	15	0.00004	0.23	9%	1.1	Incremental
Cooling	Economizer, Installation	per total bldg. ft2	15	0.00000	0.31	9%	0.9	Incremental
Ventilation	Fans, Energy-Efficient Motors	per total bldg. ft2	10	0.00002	0.13	5%	0.7	Incremental
Ventilation	Fans, Variable Speed Control	per total bldg. ft2	10	0.0001	0.39	15%	1.7	Incremental
Cooling	HVAC Retrocommissioning	per total bldg. ft2	4	0.00005	0.30	9%	2.1	Incremental
Cooling	Pumps, Variable Speed Control	per total bldg. ft2	10	0.00	0.01	1%	2.2	Incremental
Lighting	Compact Fluorescent Lamps	per total bldg. ft2	5	0.00001	0.08	67%	0.1	Full
Lighting	Fluorescent, High Bay Fixtures	per total bldg. ft2	11	0.00001	0.06	4%	3.5	Full
Lighting	T8 lamps and fixtures	per total bldg. ft2	10	0.0001	0.73	20%	5.2	Full
Lighting	LED lamps	per total bldg. ft2	10	0.0002	1.19	88%	15.5	Full
Lighting	LED Exit Lighting	per total bldg. ft2	10	0.00	0.01	94%	0.0	Full
Lighting	Metal Halide Lighting	per total bldg. ft2	10	0.0002	1.12	80%	21.4	Full
Industrial	High Efficiency Motors	per HP	20	0.0079	45.00	13%	50.3	Incremental

Avoided Costs

For conducting the economic screening of the energy efficiency measures, we considered avoided energy costs at two levels. At the first level, we considered avoided energy costs currently in place in KSA. At the second level, we escalated avoided energy costs by a factor of 5.3, in order to approximate what market-based avoided energy costs based on the international price of oil would represent.[104] The rationale for including the higher so-called "shadow" avoided energy costs is to better represent how EE might be assessed throughout the rest of the world. This approach also enabled the *Brattle* team to consider the most comprehensive range of EE measures for possible implementation within the KSA. Benefit-cost ratio calculations for all energy efficiency measures are provided at both levels of avoided energy costs. For assessing benefits from cooling measures, peak period avoided energy costs for the summer season were considered. For all other measures, a weighted average of both peak and off-peak period energy costs for both summer and winter months was considered. Table 7-9 lists these costs at current and market-based levels.

Along with avoided energy costs, we also considered avoided capacity costs (including generation and T&D) to account for the demand savings benefit associated with energy efficiency measures. The avoided capacity cost assumptions are identical to those considered for the LM/DR analysis. The avoided cost per kW-year of generating capacity and T&D capacity is 321 SR/kW-year (236 SR/kW-year for capacity and 85 SR/kW-year for T&D).

[103] *Ibid.* 100.
[104] Source: ECRA.

Table 7-9: Avoided Energy Costs at Current and Market-Based Levels

Time Period	TOU Hours	Current KSA Avoided Energy Costs (SR/MWh)	Shadow Avoided Energy Costs (SR/MWh)
Summer Peak	500	60	318
Summer Off-Peak	3150	50	264
Winter Peak	700	40	213
Winter Off-Peak	4410	35	185

7.2.2 The EE Economic Screen

Based on the methodology mentioned earlier, benefit-cost (B/C) ratios were calculated for qualitatively-screened energy efficiency measures for each of the four sectors: residential, commercial, government, and industrial. Along with B/C ratios, levelized costs were also calculated for each measure over the measure lifetime, indicated earlier in Table 7-5 to Table 7-8. The levelized cost is calculated by taking the up-front capital cost associated with the measure and dividing it by the savings that the measure produces over its lifetime. For example, assume that a high efficiency room air conditioner costs about 1350 SRs more than the standard unit. That unit will save roughly 1,040 kWh per year for its 14-year lifetime. Using a discount rate of 10%, the levelized cost is estimated to be 18 halala/kWh. All calculations assumed a discount rate of 10%, the same assumption that was used for the LM/DR economic analysis. B/C ratios are presented for the two levels of avoided energy costs, as indicated in Table above.

Residential Sector Economic Screen Results

Figure 7-10 shows the B/C ratios for all residential measures indicated earlier in Table 7-5, while Figure 7-11 indicates the levelized costs associated with these measures. An example of a typical measure in a household would be compact fluorescent lamps (CFLs). They are estimated to save over 70 kWh per year, assuming a 60 watt incandescent lamp is replaced with a 20 watt CFL. With an incremental cost of about 25 SR per lamp, the measure has a B/C ratio of 1.19 and a levelized cost of 9 halala/kWh over its 5 year lifetime.

The analysis results reveal that all residential cooling measures emerge as cost-effective for KSA. This includes central AC systems, split AC systems, and room AC systems. Central and split AC systems have lower levelized costs as compared to room AC systems. The reason for cooling measures being cost-effective even at current KSA avoided energy costs is due to the high peak demand reduction contribution from cooling measures. Associated with cooling, installation of Programmable Thermostats also emerges as highly cost-effective, primarily due to demand savings benefit associated with the measure.

Among building shell measures, wall insulation is extremely cost-effective at current KSA avoided energy costs. In fact, among all residential energy efficiency measures, this emerges as the most cost-effective option. Even ceiling insulation is cost-effective under current KSA avoided energy costs. Insulation measures typically have relatively low costs associated with them in new construction applications but even in retrofit applications they have can yield significant benefits due to the relatively large energy savings for the summer season.

A few of the residential appliances such as high efficiency TVs and other home electronic items, along with home office equipment, also emerge as highly cost-effective measures even at current (heavily subsidized) levels of avoided energy costs at KSA. The primary reason for their cost-effectiveness is the low incremental costs associated with stepping up the efficiency levels for these types of equipment.

Among the lighting measures, only CFLs are cost-effective at current levels of avoided energy costs. However, all other lighting measures such as LEDs and T8 lamps emerge cost-effective under higher levels of shadow prices. Water heating measures are not cost-effective at current levels of avoided energy costs in the Kingdom, but emerge cost-effective under shadow prices. Among home appliances, only dishwashers emerge cost-effective under shadow prices. None of the home appliances are cost-effective at current levels of avoided energy costs in KSA. High efficiency windows remain uneconomic even at the market-based avoided energy costs, primarily due to the relatively high capital cost associated with the measure. Capital costs for new construction window measures tend to be lower, but not enough to overcome the higher cost under replacement scenarios.

Figure 7-11 further reveals that many of the residential EE measures appear to have levelized costs that are substantially lower than the KSA's retail rate for electricity (which is slightly greater than 10 halala/kWh).

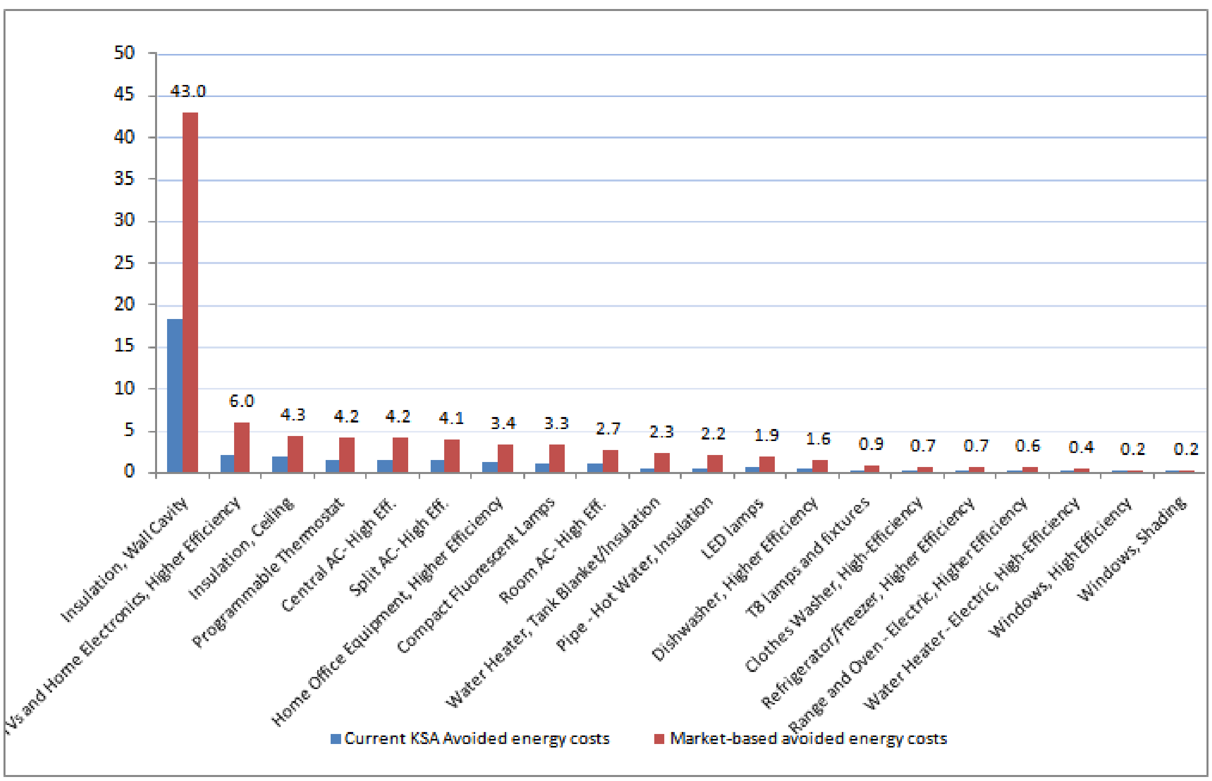

Figure 7-10: B/C Analysis Results for Residential EE Measures

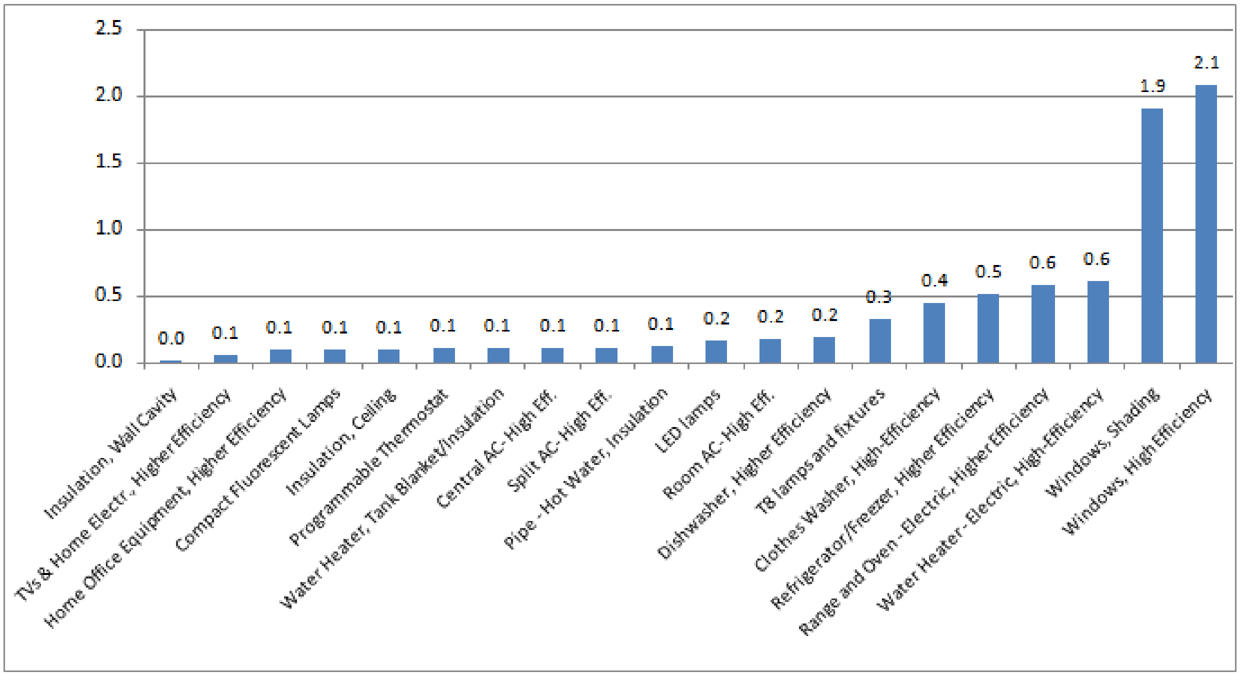

Figure 7-11: Levelized Costs for Residential EE Measures (SR/kWh)

Commercial Sector Economic Screen Results

For the commercial sector, a number of cooling, ventilation, lighting, building shell and refrigeration measures were analyzed. Different types of cooling measures were analyzed including split systems, packaged units, and central chiller based systems. Figure 7-12 and Figure 7-13 show B/C ratios and levelized costs for all of the commercial measures indicated earlier in Table 7-6. An example of a typical measure in a commercial office building would be high efficiency packaged air conditioning systems. Typical installations in locations that are comparable to the climatic conditions in the KSA are estimated to save approximately 0.77 kWh/square foot per year, assuming that the EER is improved from 8.5 to 10.1. With an incremental cost of about 75 halala per square foot, the measure has a B/C ratio of 0.59 and a levelized cost of 22 halala/kWh per square foot over its 14 year lifetime. Another example of a commercial sector measure is LED exit lighting. The estimated savings for these measures in retail and office buildings is 0.01 kWh/sqare foot per year, assuming that 2 40-watt incandescent lamp are replaced by one 5-watt LED lamp. With an incremental cost of 0.5 halala per square foot, the measure has a B/C ratio of 1.38 and a levelized cost of 8 halala/kWh per square foot over its 10 year lifetime.

At current levels of avoided energy costs in the KSA, the only two measures that emerge as cost-effective are higher efficiency Split AC units and LED exit lighting for various commercial buildings (e.g., hotels, restaurants, malls and stores, offices, retail, and hospitals) (see Figure 7-12). This is primarily due to the relatively low costs and high energy savings associated with installing these measures.

Higher levels of avoided energy prices substantially change the results of the cost-effectiveness analysis. Under the market-based avoided energy costs, a number of cooling measures emerge cost-effective, including packaged AC units, higher efficiency chillers, and economizer installation. District cooling is also assessed to be cost-effective under shadow prices. Specific cooling-related measures such as HVAC retro-commissioning and installing VSDs on chillers, remain uneconomic even under higher market-based avoided energy costs. None of the lighting measures are cost-effective under current levels of avoided energy costs in KSA. Except CFLs, all other commercial lighting measures such as T8 lamps, metal halide lighting, high bay fixtures for fluorescent lamps, and LED lamps remain uneconomic even under the market-based avoided energy cost scenario. The relatively high costs associated with all of these measures outweigh the potential energy savings benefit.

Among the other end-uses considered for the commercial sector, none of the refrigeration measures emerge cost-effective. Other than strip curtain installation, all refrigeration measures have relatively high costs associated with them.

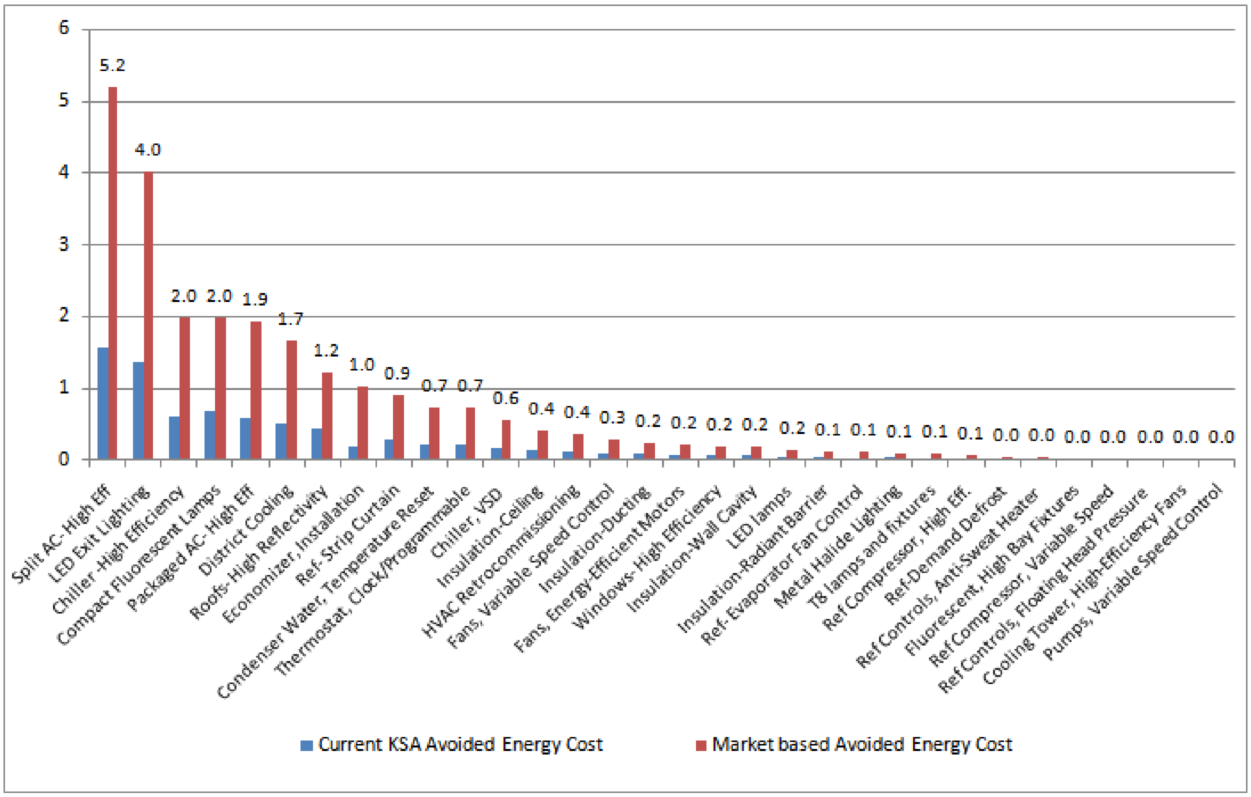

Figure 7-12: B/C Analysis Results for Commercial EE Measures

We also considered a number of building shell measures for commercial buildings, especially for new construction. Among the building shell measures considered for the commercial sector, only high reflectivity roofs for new construction emerge cost-effective under shadow prices. None of the other building shell measures including different types of insulation and higher efficiency windows are assessed to be not cost-effective even under higher levels of shadow prices, due to the relatively high costs associated with these measures.

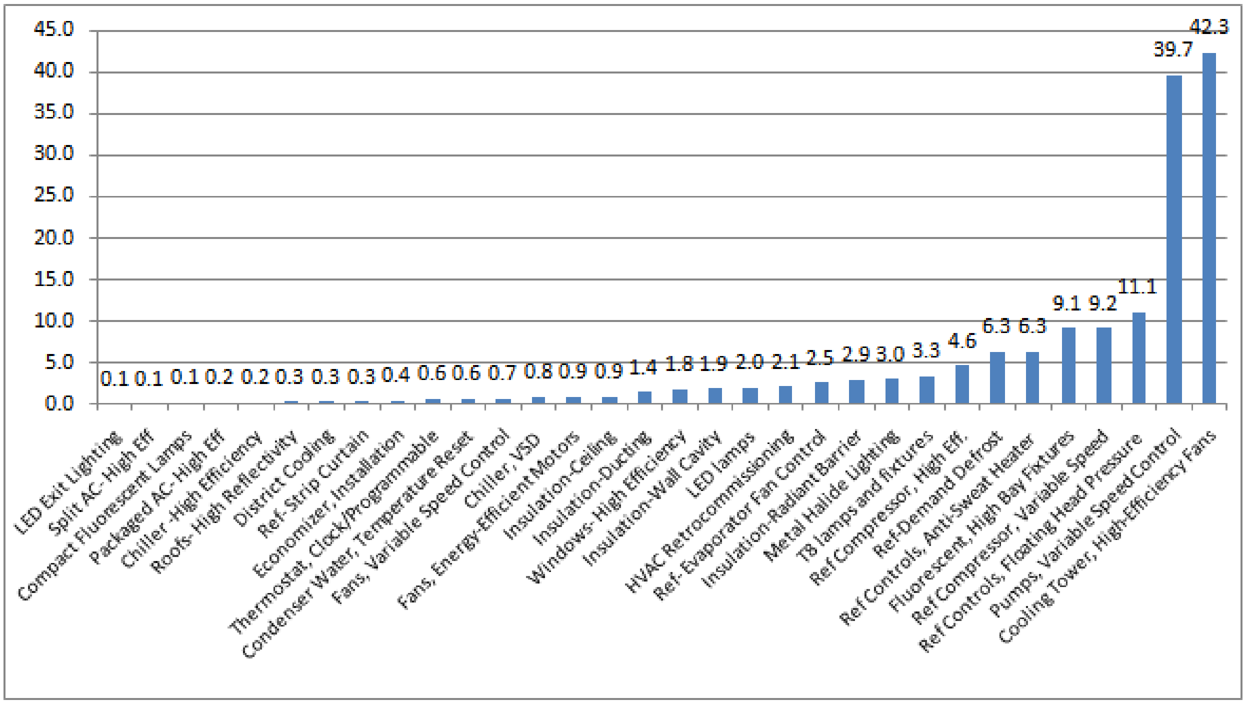

Figure 7-13: Levelized Costs for Commercial EE Measures (SR/kWh)

Government Sector Economic Screen Results

The economic analysis results for the government sector are similar to those presented for the commercial sector. Unlike commercial, measures that are specific to the government sector include street-lighting and municipal water pumping. Figure 7-14 and Figure 7-15 show B/C ratios and levelized costs for all government sector measures indicated earlier in Table 7-6. An example of a typical measure in the government sector would be high efficiency motors for water pumping. These measures are estimated to about 45 kWh/horsepower per year, assuming a standard efficiency pump is replaced with a high efficiency pump. With an incremental cost of about 50 SR per horsepower, the measure has a B/C ratio of 0.92 and a levelized cost of 13 halala/kWh over its 20 year lifetime.

Among the street lighting measures included in the analysis, high pressure sodium lamps and metal halide lamps emerge economic even at current levels of energy prices in the Kingdom, since they have relatively low levels of levelized costs. Among other government sector-specific measures, municipal pumping is marginally cost-effective at current energy price levels (B/C ratio of 0.9), since undertaking improvements for higher efficiency water pumping is likely to reap significant benefits. The cost-effectiveness of the cooling, lighting, and building shell measures for the government sector are similar to what has been presented earlier for the commercial sector. Similar to the results for the commercial sector, only higher efficiency Split AC units are cost-effective under current levels of avoided energy costs in the Kingdom.

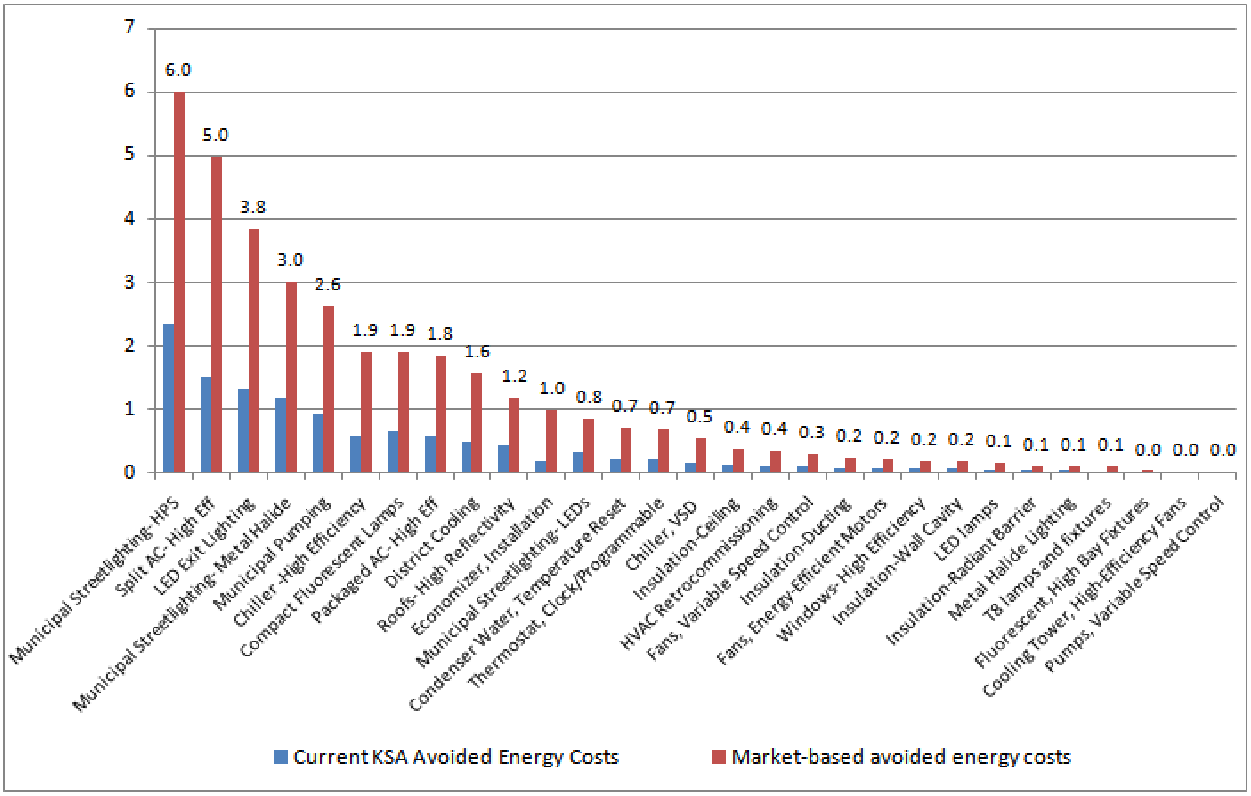

Figure 7-14: B/C Analysis Results for Government EE Measures

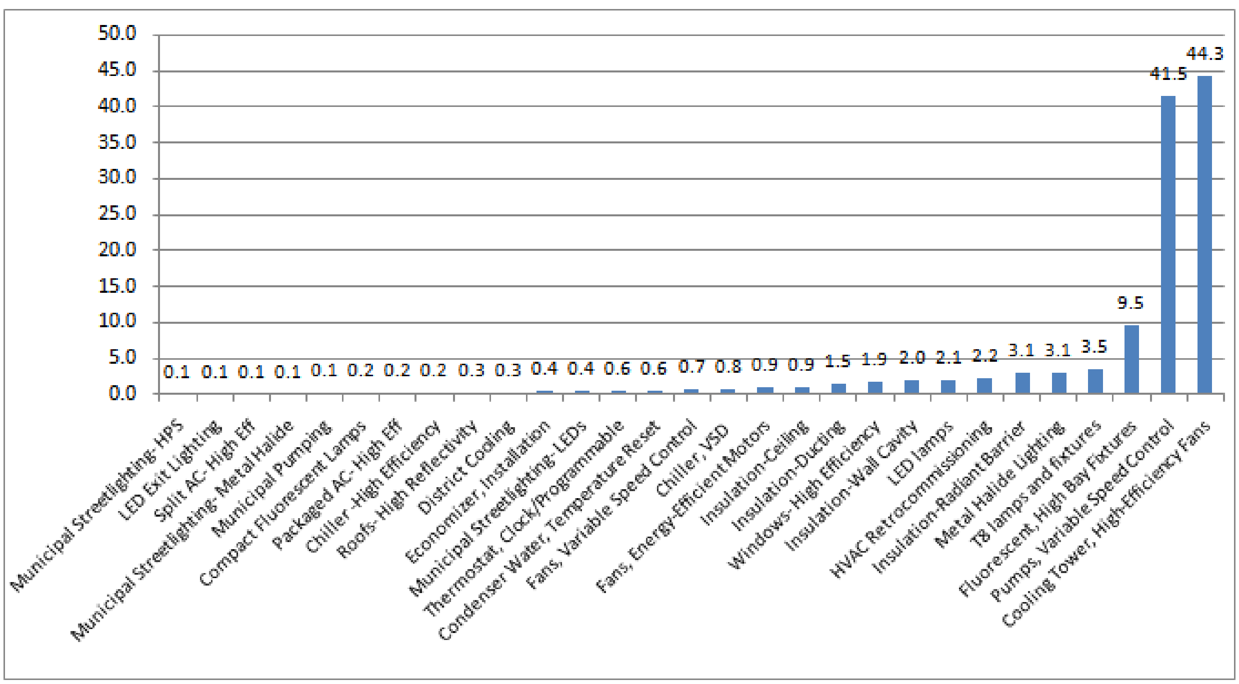

Figure 7-15: Levelized Costs for Government EE Measures (SR/kWh)

Industrial Sector Economic Screen Results

Figure 7-16 shows B/C ratios and levelized costs for industrial sector measures indicated earlier in Table 7-8. An example of a typical measure in the industrial sector would be high efficiency motors for industrial processes. These measures are estimated to about 45 kWh/horsepower per year, assuming a standard efficiency motor is replaced with a high efficiency moor. With an incremental cost of about 50 SR per horsepower, the measure has a B/C ratio of 0.92 and a levelized cost of 13 halala/kWh over its 20 year lifetime.

At current levels of avoided energy costs applicable to the KSA, higher efficiency improvements in motors emerge nearly cost-effective, with a B/C ratio greater than 0.9. Therefore, this area presents a huge untapped potential with significant energy savings benefit. Economic analysis results for lighting and cooling measures are similar to what has been presented earlier for the commercial sector. The only cost-effective measure at current levels of avoided energy costs in the Kingdom is LED Exit lighting. CFLs for lighting are not cost-effective with a B/C ratio of 0.7

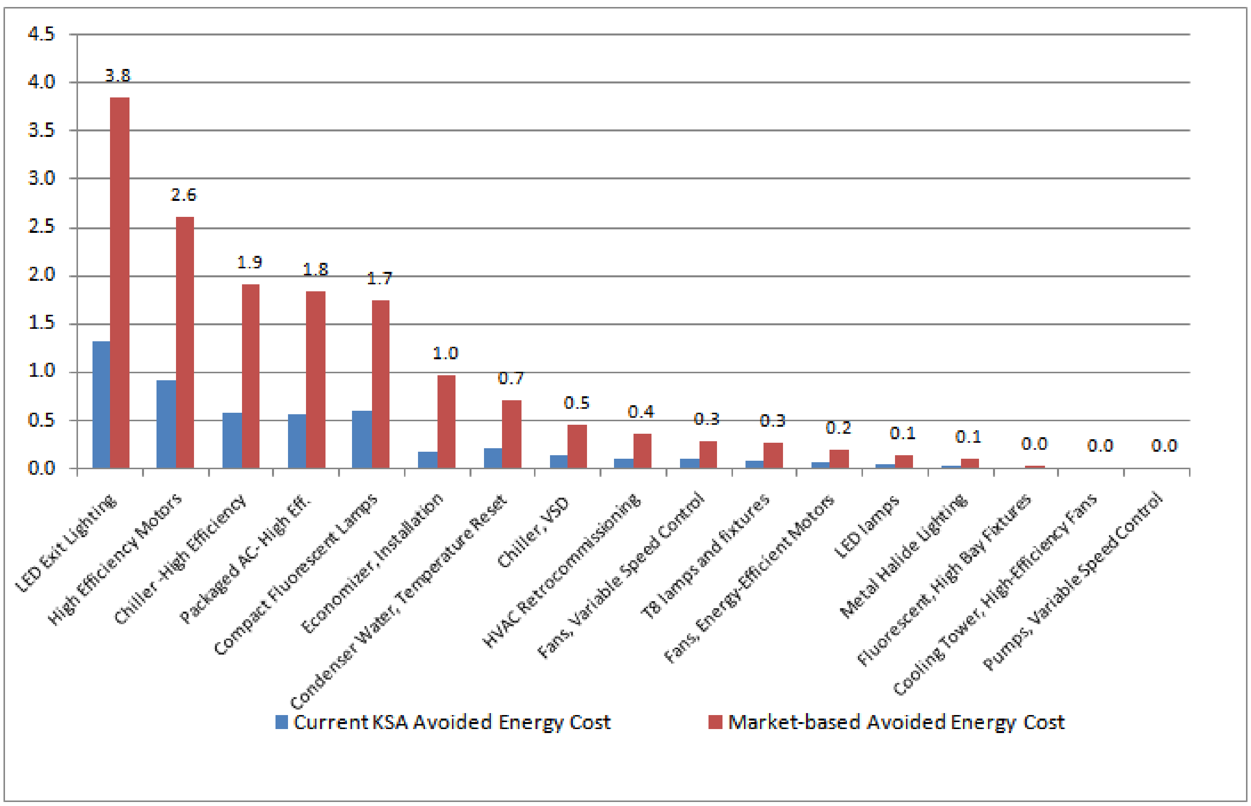

Figure 7-16: B/C Analysis Results for Industrial EE Measures

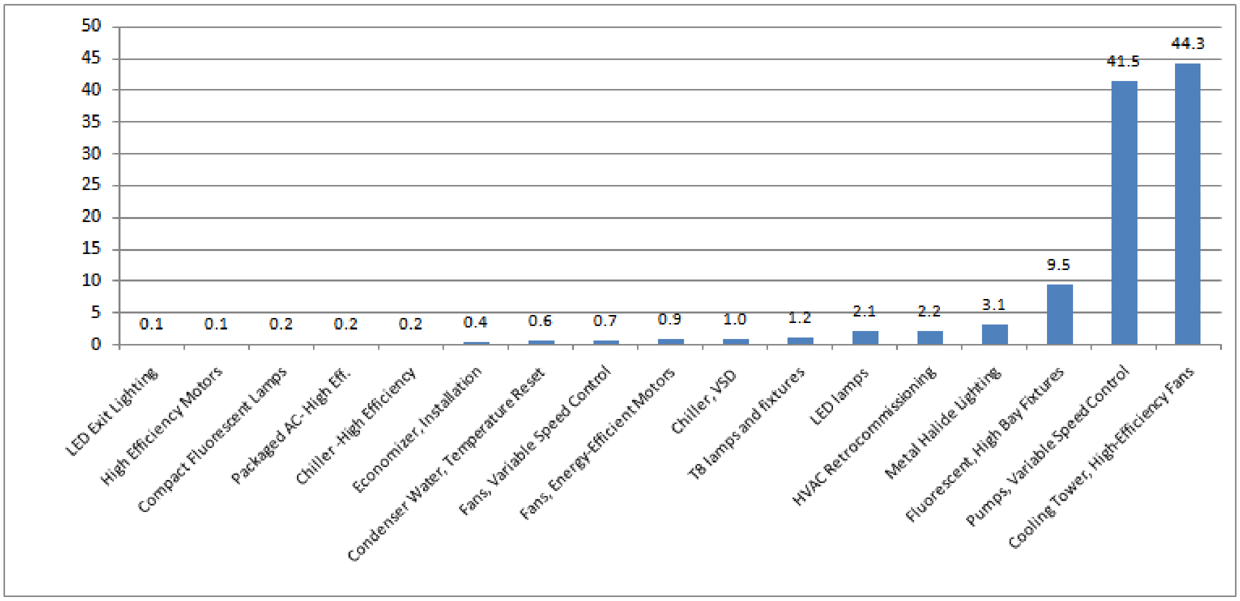

Figure 7-17: Levelized Costs for Industrial EE Measures (SR/kWh)

7.2.3 EE Measure Market Potential

In this section, market potential savings estimates are presented for all energy efficiency measures deemed applicable for possible adoption in the Kingdom. Results from the baseline analysis, presented earlier in Chapter 4, are combined with the measure-level assessment presented earlier in this chapter, to come up with KSA-wide levels of market potential for each of the energy efficiency measures considered in this study. To arrive at estimates of market potential requires the development of a wide variety of assumptions related to the technical feasibility and market acceptance associated with each individual EE measure for each of the relevant customer segments represented in the Kingdom. It is important to note that, similar to the approach adopted for LM/DR measures, market potential estimates are presented for all energy efficiency measures considered in this analysis, irrespective of their cost-effectiveness.

The general approach taken for estimating EE measure market potential is to assign a series of scale-up factors that serve as a bridge between the measure-level savings impacts (typically expressed in terms of kW and kWh saved per device or comparable unit of measurement) and the measure-level market potential savings impacts (typically expressed in terms of GW and GWh for each of the four regions and for the Kingdom as a whole). These scale-up factors are derived from KSA data (if available) on equipment saturations and typical building sizes. If there is no KSA-specific data, then an estimate is applied to arrive at the scale-up factors. For example, building sizes, assumed average roof area, etc. are represented for the various measures studied. Each of these factors are reported in the sections that follow. Figure 7-18 illustrates the steps taken to arrive at the population-level estimates of EE market potential.

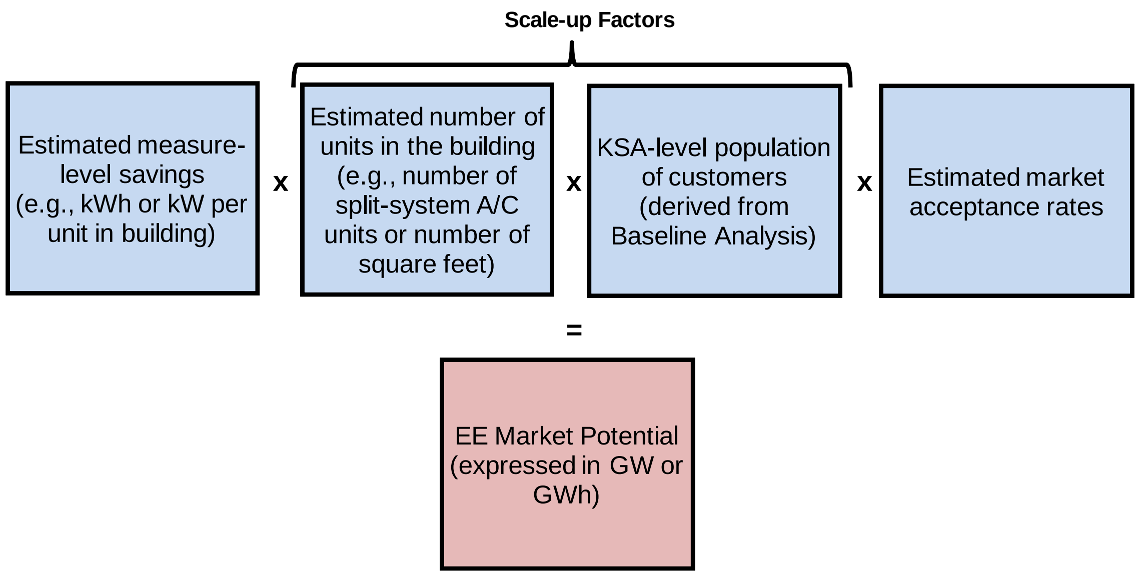

Figure 7-18: General Approach to Arrive at EE Market Potential

Table 7-11 indicates the use of market acceptance rates. These are highly subjective estimates of the likely level of customer acceptance for EE measures, should they be promoted through various energy efficiency implementation schemes in the KSA. The market acceptance rates that are used in this study were interpreted from a previous study conducted by the *Brattle* team.[105] These rates are representative of a compilation of expert opinions gathered from various industry authorities represented by utilities, third-party program administrators, regulatory authorities, and industry advocacy groups. Once the perspectives of these various groups were obtained, a Delphi-based approach was taken by the EPRI study team to establish a set of factors that would lead to participation levels that are less than 100% of what is technically feasible, and would be representative of commonly adopted incentive levels, typical expenditures for EE program administration and outreach, and regulatory barriers that are commonly experienced in EE programs. Delphi approaches are commonly used in these types of studies where primary data are not typically available. A recent study for the Energy Center of Wisconsin on the potential for EE in the US state of Wisconsin employed a Delphi process for gathering expert input on what could be achieved under a future scenario of aggressive energy efficiency policy and program efforts.[106]

The approaches taken and market potential results for each of the sectors are presented in the sections that follow.

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105 *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

106 Energy Center of Wisconsin. "Energy Efficiency and Customer-Sited Renewable Resource Potential in Wisconsin for the years 2012 and 2018." April 2009. (Report co-authors ACEEE, GDS Associates and L&S Technical Associates).

Residential Sector EE Market Potential

A. Approach for Estimating Residential Sector Market Potential

To arrive at the residential sector market potential, several steps were taken. First, the technical potential for each measure was estimated, drawing on the unit savings data for the measure. The technical potential associated with a measure indicates the maximum amount of potential associated with a measure, irrespective of cost-effectiveness of the measure, and assuming 100% participation rates. It represents an upper bound on the potential and can be considered as a theoretical concept.

Table 7-10 lists the assumptions used for scaling up unit measure level savings to the aggregate technical potential estimation for the entire residential sector. The market potential estimation assumes that only a certain percentage of the market will adopt those measures that are cost-effective. The market potential estimates take into account factors related to market acceptance and program implementation. These factors serve to estimate the portion of the market that might potentially participate in future EE programs. Table 7-11 summarizes the market acceptance rates that were applied to the eligible customer segment in order to come up with Kingdom-wide levels of market potential for each of the residential EE measures. The acceptance rates assume that the customer is given some type of incentive to encourage their participation.

As an example, for central cooling, the aggregate technical and market potentials were derived using the following formulae:

Aggregate technical potential for central cooling = Annual kWh savings per central AC unit * Average number of AC units per Household * Percentage of residential customers with central AC units (saturation) * Total number of residential customers

Aggregate market potential for central cooling = Aggregate technical potential for central cooling * Market acceptance and Implementation factor

Applying numbers to the formulae outlined above, we will now provide an example for a typical residential building. First, we will use a large existing villa that is approximately 1,000 square meters in size. Let us assume that the annual kWh savings per central AC unit is estimated to be 5,564 kWh. This estimate was derived using engineering models that simulate actual weather conditions comparable to the characteristics in the KSA. Now we will assume that this villa has 3 central air conditioning units to serve the cooling requirements for the whole building. Based on limited equipment saturation data for the KSA, we know that roughly 5% of the residential sector buildings in the KSA have central AC. Finally, there are nearly 5 million residential buildings in the KSA. Based on these facts, the aggregate technical potential for central cooling is calculated as follows:

*5,564 kWh savings per unit * 3 units per HH * 5% saturation * 4,897,474 residential buildings = 4,087,431,800 kWh*

Table 7-10: Scaling-Up Assumptions for Residential EE Measures[107]

End-Use	Energy Efficiency Measure	Scaling up factor units	Scaling up factor values	Measure saturation (% of residential customers)
Cooling	Central AC- High Eff.	# of AC units per Hhold	3	5%
Cooling	Split AC- High Eff.	# of AC units per Hhold	3	10%
Cooling	Room AC- High Eff.	# of AC units per Hhold	5	85%
Cooling	Programmable Thermostat	# of thermostats per Hhold	3	17%
Building	Insulation, Ceiling	Average ft2 of roof area	750	49%
Building	Insulation, Wall Cavity	Average ft2 of wall area	1500	49%
Building	Windows, High Efficiency	Average ft2 of window area	500	49%
Building	Windows, Shading	Average ft2 of window area	500	49%
Lighting	Compact Fluorescent Lamps	# of lamps per Hhold	10	80%
Lighting	T8 lamps and fixtures	# of lamps per Hhold	13	80%
Lighting	LED lamps	# of lamps per Hhold	4	100%
Water Heating	Pipe - Hot Water, Insulation	# of water heaters per Hhold	3	100%
Water Heating	Water Heater, Tank Blanket/Insulation	# of water heaters per Hhold	3	100%
Water Heating	Water Heater - Electric, High-Efficiency	# of water heaters per Hhold	3	100%
Appliances	Clothes Washer, High-Efficiency	# of appliances per Hhold	1	94%
Appliances	Dishwasher, Higher Efficiency	# of appliances per Hhold	1	49%
Appliances	Home Office Equipment, Higher Efficiency	# of appliances per Hhold	1	100%
Appliances	Range and Oven - Electric, Higher Efficiency	# of appliances per Hhold	1	44%
Appliances	Refrigerator/Freezer, Higher Efficiency	# of appliances per Hhold	2	99%
Appliances	TVs and Home Electronics, Higher Efficiency	# of appliances per Hhold	2	97%
Notes:				
Average sq.ft. of roof area, wall area, and window area based on estimation				

[107] NEEP, Volume 2A.

Table 7-11: Market Acceptance Rates for Residential EE Measures[108]

End-Use	Energy Efficiency Measure	Measure saturation (% of residential customers)
Cooling	Central AC- High Eff.	5%
Cooling	Split AC- High Eff.	10%
Cooling	Room AC- High Eff.	85%
Cooling	Programmable Thermostat	17%
Building	Insulation, Ceiling	49%
Building	Insulation, Wall Cavity	49%
Building	Windows, High Efficiency	49%
Building	Windows, Shading	49%
Lighting	Compact Fluorescent Lamps	80%
Lighting	T8 lamps and fixtures	80%
Lighting	LED lamps	100%
Water Heating	Pipe - Hot Water, Insulation	100%
Water Heating	Water Heater, Tank Blanket/Insulation	100%
Water Heating	Water Heater - Electric, High-Efficiency	100%
Appliances	Clothes Washer, High-Efficiency	94%
Appliances	Dishwasher, Higher Efficiency	49%
Appliances	Home Office Equipment, Higher Efficiency	100%
Appliances	Range and Oven - Electric, Higher Efficiency	44%
Appliances	Refrigerator/Freezer, Higher Efficiency	99%
Appliances	TVs and Home Electronics, Higher Efficiency	97%

B. Energy Savings Potential for Residential EE Measures

Following the approach outlined above, Figure 7-19 presents the results of the residential market potential analysis, which are presented for the year 2012. Figure 7-20 presents the market potential results as % of the residential baseline energy forecast for 2012.

Not surprisingly, cooling measures have the highest share in the market potential since they constitute a very large fraction of the residential energy use. Among cooling measures, Room AC units with relatively high saturation have the largest amount of energy savings potential, followed by Split AC and Central AC units. These three cooling measures combined have almost 15% energy reduction potential for the residential sector by 2012.

[108] Market acceptance rates derived from a widely circulated report that was prepared jointly by Global Energy Partners and The Brattle Group, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

As indicated in Figure 7-19, the second highest level of potential after Room AC units in the residential sector is associated with high efficiency clothes washers at 3.5% of the residential electricity use in 2012. Other home appliances such as higher efficiency dishwashers and refrigerators/freezers have medium levels of potential associated with them, while highly cost effective appliance such as high efficiency TVs and home electronics along with higher efficiency home office equipment have relatively low levels of energy savings potential.

Among residential lighting measures, energy savings potential associated with CFL lamps are the largest. The savings potential from CFL lamps is estimated to be around 1.4% of the overall residential sector electricity use in 2012. Recall that for the residential sector, CFL lamps are cost-effective even under current levels of avoided energy costs in KSA. Therefore, CFLs do offer promise for reaping significant benefits for the residential sector in the near term. LED lamps too offer around 1% energy savings potential in 2012, but are not cost-effective under current avoided energy costs (B/C ratio of 0.7). T8 lamps have relatively much lower level of energy savings potential. These lamps too are uneconomic at current levels of avoided energy costs, but are nearly cost-effective at market-based avoided energy costs.

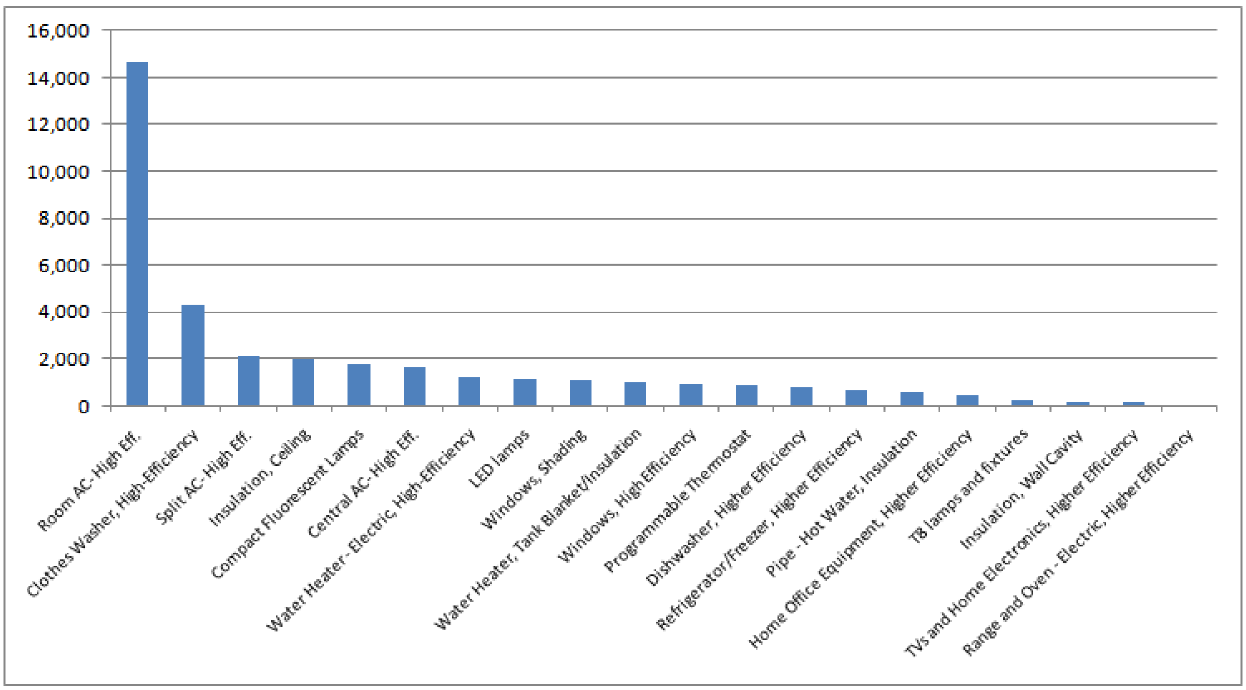

Figure 7-19: Market Potential for Residential EE Measures in 2012 (GWh)

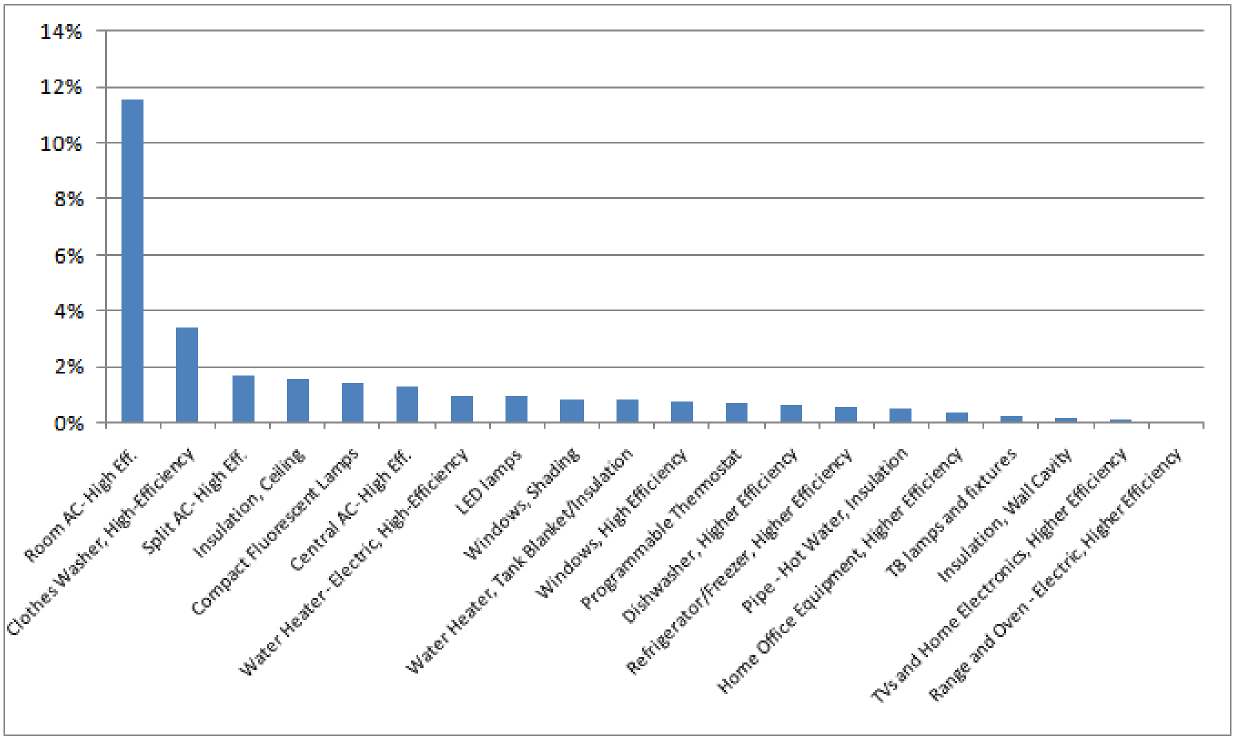

Figure 7-20: Residential Sector Market Potential for EE (as % of 2012 baseline energy forecast)

Among the building envelope measures considered in our analysis, ceiling insulation offers the largest amount of potential. Also, ceiling insulation is an extremely cost-effective measure. Therefore, this emerges as the most attractive option for consideration in the near term. Wall insulation, on the other hand, has very low level of potential even though it is a highly cost-effective measure. This is due to the relatively low applicability of this measure due to the block wall construction that is prevalent in the KSA residential building stock. Higher efficiency windows have moderate levels of potential associated with them, but are not cost-effective even at market-based avoided energy cost levels. These measures tend to be expensive as retrofits to existing buildings but can be quite attractive in new construction programs. Higher efficiency electric water heater offers moderate level of energy savings potential, but is not cost-effective even under shadow price conditions. Additionally, insulation of the water heater tank and hot water pipe insulation too offer moderate energy savings potential and is cost-effective under shadow price conditions.

Figure 7-21 presents demand savings potential associated with energy efficiency measures in 2012. Figure 7-22 represents the potential as percentage of the residential peak in 2012. Not surprisingly, Room AC, with the highest level of energy savings potential, also have the highest level of demand of demand savings potential associated with it. Split and Central AC units too have moderate levels of energy savings potential. These three cooling measures combined therefore offer an attractive opportunity for residential peak demand reduction. Also, higher efficiency clothes washer offer substantial demand savings opportunities. Ceiling insulation too has potential to reap significant demand savings by reduction in cooling load. Similarly, other building shell measures such as higher efficiency windows have moderate levels of demand reduction potential and could be targeted in the medium term. Among the lighting measures, CFLs have a 1% demand savings potential by 2012, followed by LED lamps at 0.8%. All other measures considered in our analysis have relatively low contribution in the overall demand savings potential from residential energy efficiency measures.

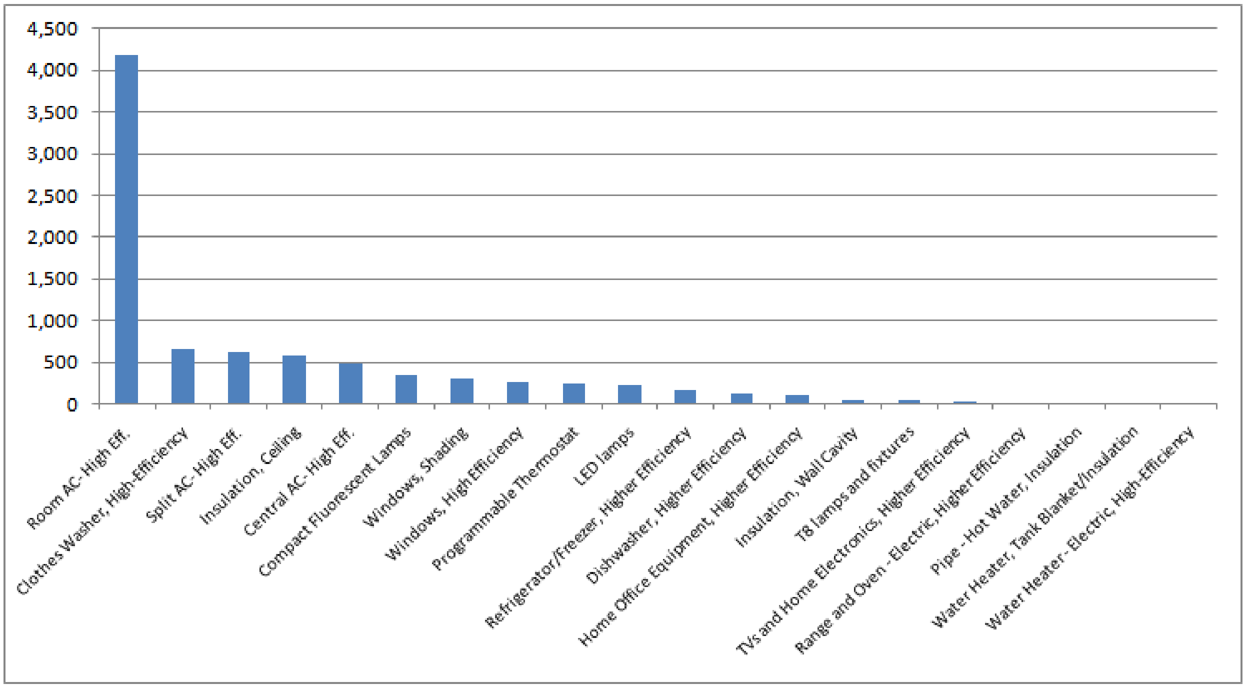

Figure 7-21: Market Potential for Residential EE Measures in 2012 (MW)

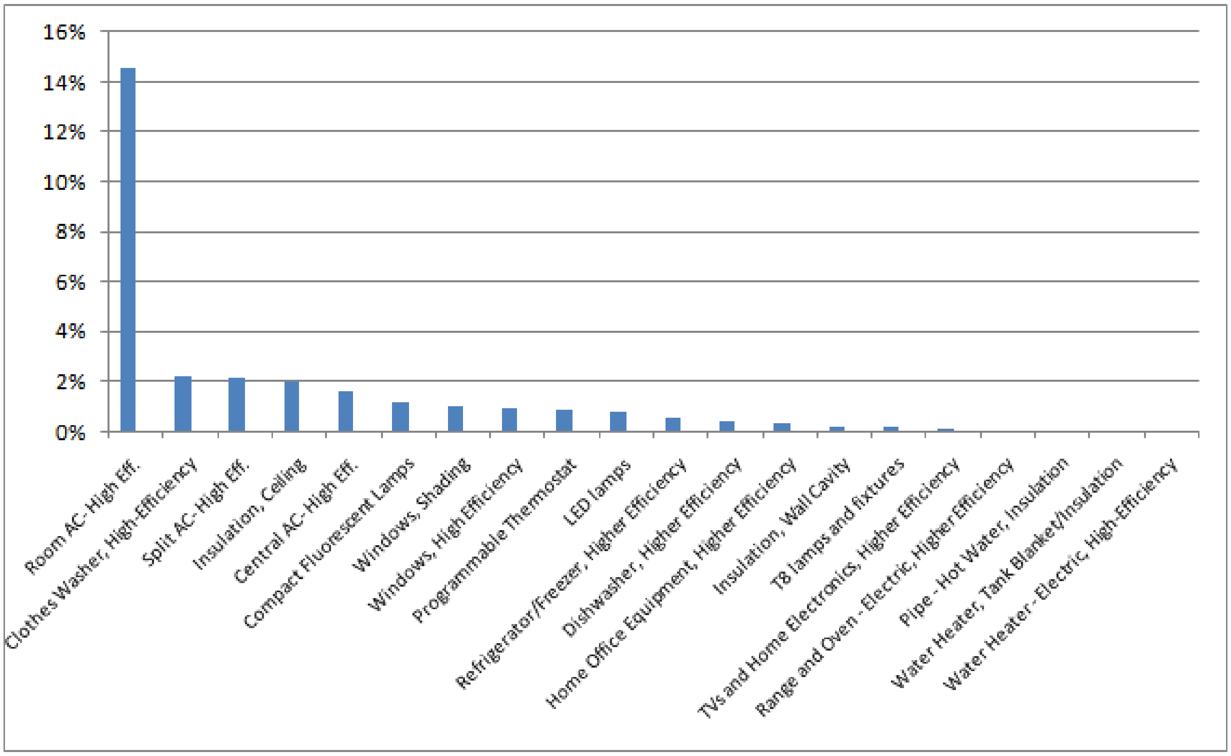

Figure 7-22: Residential Sector Market Potential for EE (as % of 2012 peak demand forecast)

C. EE Measure Potential by Operating Area

Due to differences in the customer mix, peak load, and sales in each operating area, the EE measure potential tends to vary geographically. Figure 7-23 illustrates the allocation of each measure's market potential by operating area within the KSA.

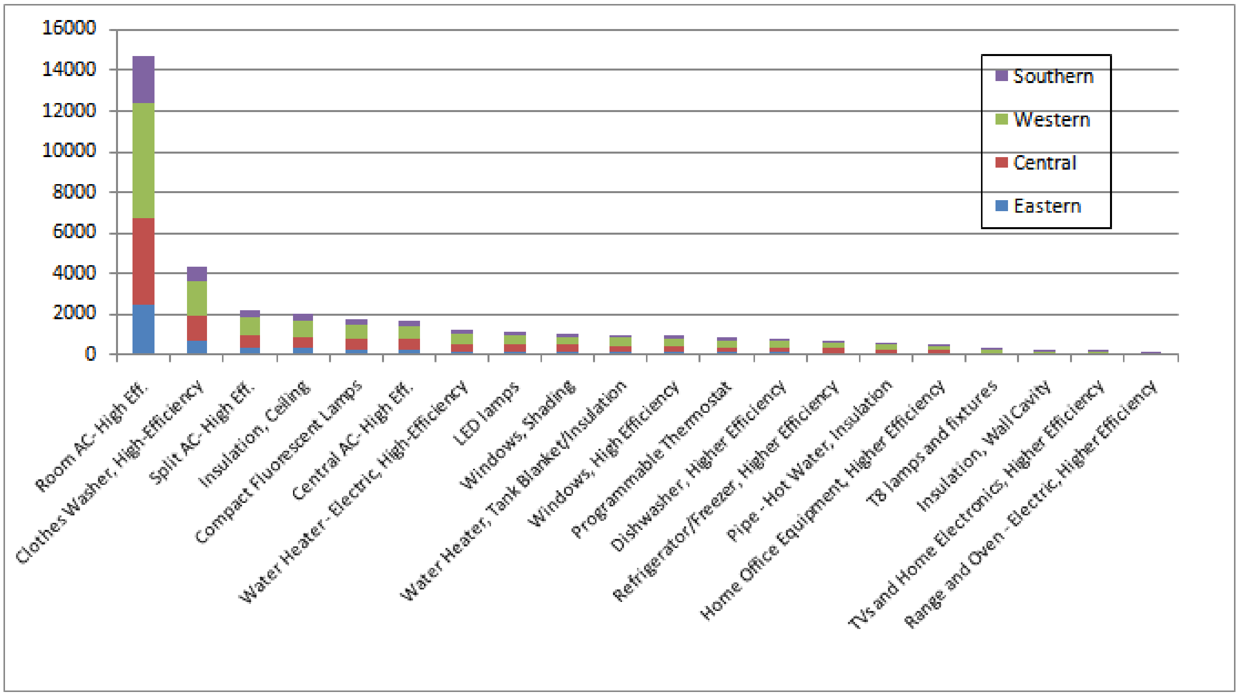

Figure 7-23: Residential Sector Market Potential for EE by KSA Region in 2012 (GWh)

The vast majority of the residential market potential is in the Western and Central operating areas, which is where most of the country's residential customers are located. The western region has close to 40% share in the energy savings potential from residential measures, followed by the central region at 30% share. Eastern and southern regions have 17% and 15% shares respectively in the national level potential.

D. Growth in EE Measure Potential over Time

As the residential population and sales grow, the potential impact of each measure will grow as well. At the system level, this can be quite significant, with the potential impact of the measures growing by more than 50 percent over the next decade. Figure 7-24 illustrates the increase in measure potential between 2011 and 2021.

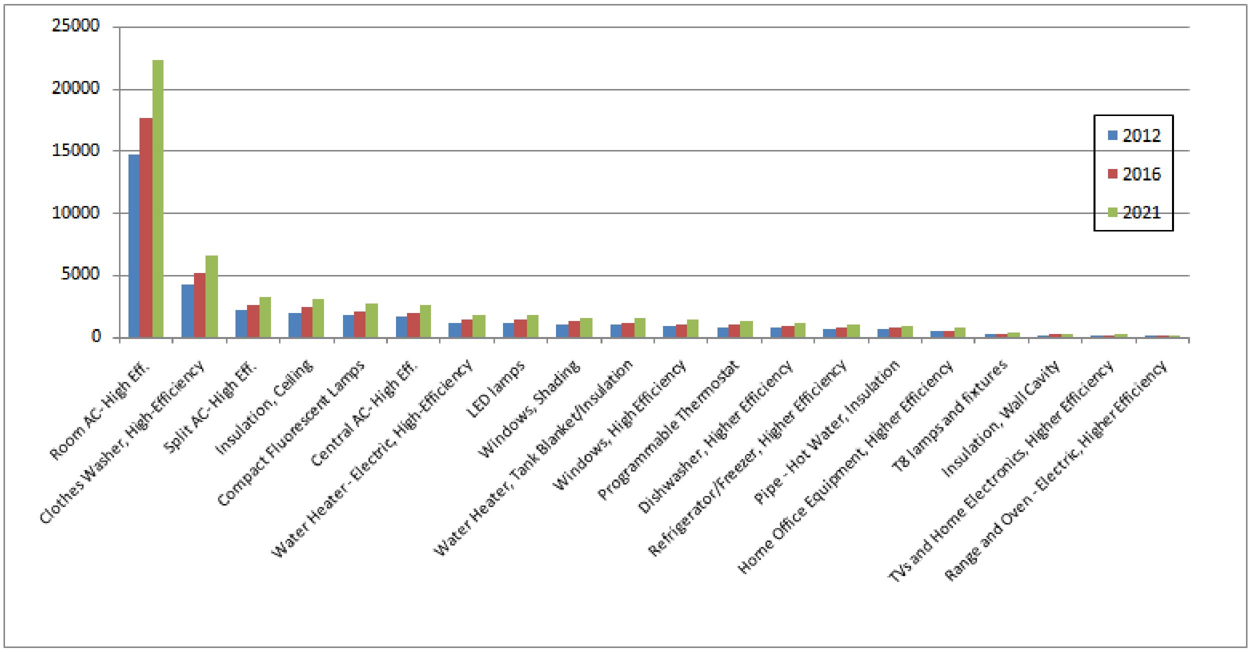

Figure 7-24: Residential Sector Market Potential for EE by Year (GWh)

Commercial Sector EE Market Potential

A. Approach for Estimating Commercial Sector Market Potential

The approach taken to arrive at the commercial sector market potential is similar to the one adopted for the residential sector. First, the technical potential for each measure was estimated, drawing on the unit savings data for the measure. The technical potential associated with a measure indicates the maximum amount of potential associated with a measure, irrespective of cost-effectiveness of the measure, and assuming 100% participation rates. It represents an upper bound on the potential and can be considered as a theoretical concept.

Table 7-12 lists the assumptions used for scaling up unit measure level savings to the aggregate technical potential estimation for the entire commercial sector. Savings at the unit measure level are expressed in terms of per square footage. Therefore the average square footage for a typical building to which the measure applies is used as a scaling up factor.

The market potential estimation assumes that only a certain percentage of the market will adopt those measures that are cost-effective. The market potential estimates take into account factors related to market acceptance and program implementation. These factors serve to estimate the portion of the market that might potentially participate in future EE programs.

Table 7-13 summarizes the market acceptance rates that were applied to the eligible customer segment in order to come up with Kingdom-wide levels of market potential for each of the commercial EE measures.

As an example, for Packaged AC units, the aggregate technical and market potentials were derived using the following formulae:

Aggregate technical potential for Packaged AC units = Annual kWh savings per square foot of building floor area from Packaged AC units * Average square feet for applicable building type (in this case typical retail size building) * Applicability Factor (based on % of buildings suitable for this measure) * Total number of commercial customers

Aggregate market potential for central cooling = Aggregate technical potential for Packaged AC units * Market acceptance and Implementation factor

Table 7-12: Scaling-Up Assumptions for Commercial EE Measures

End-Use	Energy Efficiency Measure	Applicable building size	Average square footage for applicable building type	Applicability Factor (based on percent of buildings suitable for this measure)
Cooling	Split AC- High Eff	typical small size bldg	5,000	90%
Cooling	Packaged AC- High Eff	typical retail size bldg	25,000	5%
Cooling	Chiller -High Efficiency	typical large size bldg	50,000	3%
Cooling	District Cooling	typical large size bldg	50,000	3%
Cooling	Chiller, VSD	typical large size bldg	50,000	3%
Cooling	Cooling Tower, High-Efficiency Fans	typical large size bldg	50,000	3%
Cooling	Condenser Water, Temperature Reset	typical large size bldg	50,000	3%
Cooling	Economizer, Installation	typical large size bldg	50,000	3%
Ventilation	Fans, Energy-Efficient Motors	typical large size bldg	50,000	3%
Ventilation	Fans, Variable Speed Control	typical large size bldg	50,000	3%
Cooling	HVAC Retrocommissioning	typical large size bldg	50,000	3%
Cooling	Pumps, Variable Speed Control	typical large size bldg	50,000	3%
Cooling	Thermostat, Clock/Programmable	typical small size bldg	5,000	90%
Lighting	Compact Fluorescent Lamps	average for stock of all commercial buildings	8,250	50%
Lighting	Fluorescent, High Bay Fixtures	typical retail size bldg	25,000	5%
Lighting	T8 lamps and fixtures	average for stock of all commercial buildings	8,250	50%
Lighting	LED lamps	average for stock of all commercial buildings	8,250	10%
Lighting	LED Exit Lighting	average for stock of all commercial buildings	8,250	25%
Lighting	Metal Halide Lighting	typical retail size bldg	25,000	5%
Refrigeration	Ref Compressor, High Eff.	typical retail size bldg	25,000	5%
Refrigeration	Ref Compressor, Variable Speed	typical retail size bldg	25,000	5%
Refrigeration	Ref-Demand Defrost	typical retail size bldg	25,000	5%
Refrigeration	Ref Controls, Anti-Sweat Heater	typical retail size bldg	25,000	5%
Refrigeration	Ref Controls, Floating Head Pressure	typical retail size bldg	25,000	5%
Refrigeration	Ref- Evaporator Fan Control	typical retail size bldg	25,000	5%
Refrigeration	Ref- Strip Curtain	typical retail size bldg	25,000	5%
Building shell	Insulation-Ceiling	average for stock of all commercial buildings	8,250	70%
Building shell	Insulation-Ducting	average for stock of all commercial buildings	8,250	70%
Building shell	Insulation-Radiant Barrier	average for stock of all commercial buildings	8,250	70%
Building shell	Insulation-Wall Cavity	average for stock of all commercial buildings	8,250	70%
Building shell	Roofs- High Reflectivity	average for stock of all commercial buildings	8,250	70%
Building shell	Windows- High Efficiency	average for stock of all commercial buildings	8,250	70%

Notes:

Assumptions related to average sq. footage for applicable building sizes based on estimation, depending on the applicable building type

Table 7-13: Market Acceptance Rates for Commercial EE Measures[109]

End-Use	Energy Efficiency Measure	Market Acceptance and Implementation Factors (%)
Cooling	Split AC- High Eff	38%
Cooling	Packaged AC- High Eff	38%
Cooling	Chiller -High Efficiency	38%
Cooling	District Cooling	38%
Cooling	Chiller, VSD	38%
Cooling	Cooling Tower, High-Efficiency Fans	38%
Cooling	Condenser Water, Temperature Reset	38%
Cooling	Economizer, Installation	38%
Ventilation	Fans, Energy-Efficient Motors	35%
Ventilation	Fans, Variable Speed Control	35%
Cooling	HVAC Retrocommissioning	38%
Cooling	Pumps, Variable Speed Control	38%
Cooling	Thermostat, Clock/Programmable	38%
Lighting	Compact Fluorescent Lamps	60%
Lighting	Fluorescent, High Bay Fixtures	60%
Lighting	T8 lamps and fixtures	60%
Lighting	LED lamps	60%
Lighting	LED Exit Lighting	60%
Lighting	Metal Halide Lighting	60%
Refrigeration	Ref Compressor, High Eff.	35%
Refrigeration	Ref Compressor, Variable Speed	35%
Refrigeration	Ref-Demand Defrost	35%
Refrigeration	Ref Controls, Anti-Sweat Heater	35%
Refrigeration	Ref Controls, Floating Head Pressure	35%
Refrigeration	Ref- Evaporator Fan Control	35%
Refrigeration	Ref- Strip Curtain	35%
Building shell	Insulation-Ceiling	23%
Building shell	Insulation-Ducting	23%
Building shell	Insulation-Radiant Barrier	23%
Building shell	Insulation-Wall Cavity	23%
Building shell	Roofs- High Reflectivity	23%
Building shell	Windows- High Efficiency	23%

[109] Market acceptance rates derived from study titled *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

B. Energy Savings Potential for Commercial EE Measures

Following the approach outlined earlier for estimating the aggregate market potential associated with individual EE measures, Figure 7-25 presents these results for the commercial sector. Results in Figure 7-25 are presented for the year 2012. Figure 7-26 presents the total market potential as a percentage of the commercial baseline electricity use in 2012.

Cooling constitutes the largest fraction of commercial sector energy use. The market potential analysis broadly considered three types of cooling measures: Split AC systems, Packaged AC units, and Central Chillers. Among these three broad measure types, higher efficiency Split AC units offer substantial amount of savings potential at around 10% of the overall commercial sector electricity usage in 2012 (see Figure 7-26). Also recall that higher efficiency Split AC units are also highly cost-effective under current levels of avoided energy costs in the Kingdom. Therefore, installing higher efficiency Split AC units for commercial customers clearly offers a 'low hanging fruit' opportunity in KSA, ready to be reaped in the short-term. Packaged AC units offer lower energy savings opportunities at slightly greater than 1% of the commercial energy use in 2012. Among other cooling measures considered for commercial, higher efficiency chillers and District Cooling systems offer next highest levels of potential. Both of these measures along with packaged AC units are economic under shadow price conditions. For central chiller systems, energy efficiency improvement by installing Variable Speed Drive (VSD) on chillers is estimated to have an energy savings potential slightly greater than 1% in 2012. Energy savings potential from all other cooling related measures is estimated to be less than 1% of the commercial sector use.

Next to cooling, lighting constitutes the second largest share in commercial electricity use. Within lighting, the largest amount of energy savings potential could be realized by converting incandescent lamps to higher efficiency metal halide lighting in commercial buildings. This measure, just by itself, is estimated to have a savings potential of around 2.5% of the energy use in 2012. However, recall that this measure is not cost-effective even under shadow price conditions. Other lighting measures such as LED and T8 lamps also offer savings potential at 1-2% of the commercial sector energy use in 2012. CFLs only have 0.2% energy savings potential for the commercial sector.

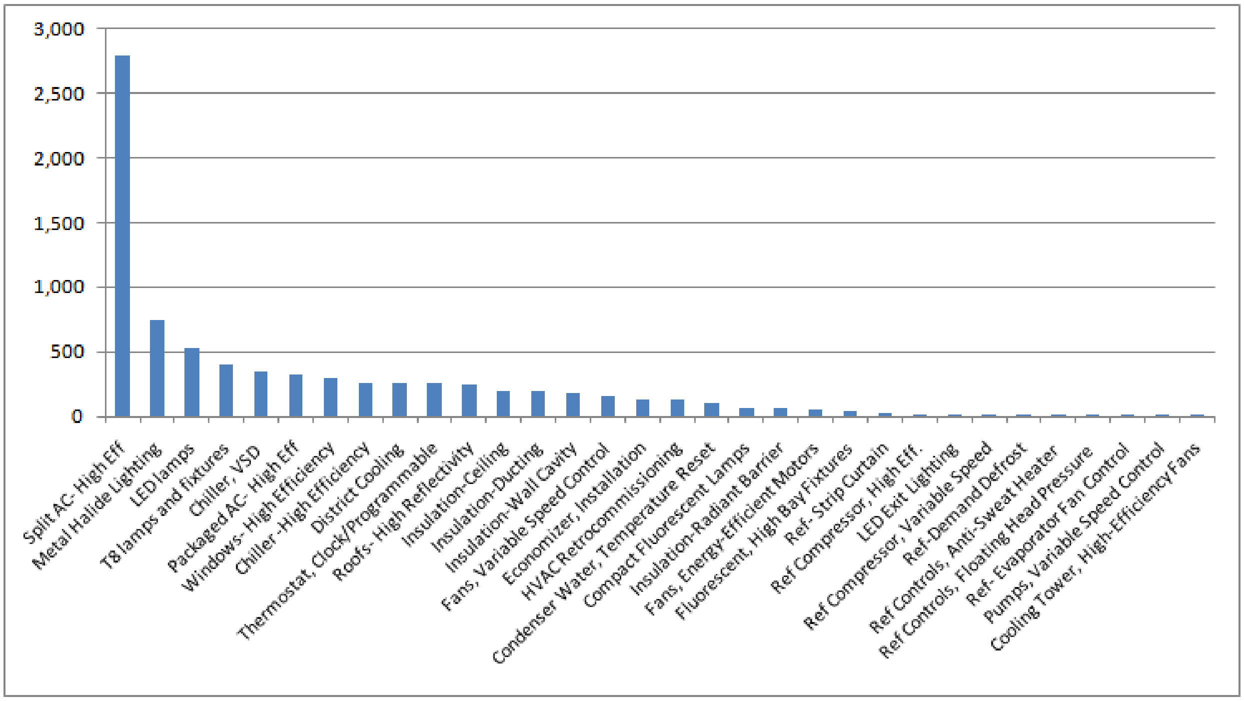

Figure 7-25: Market Potential for Commercial Sector EE Measures in 2012 (GWh)

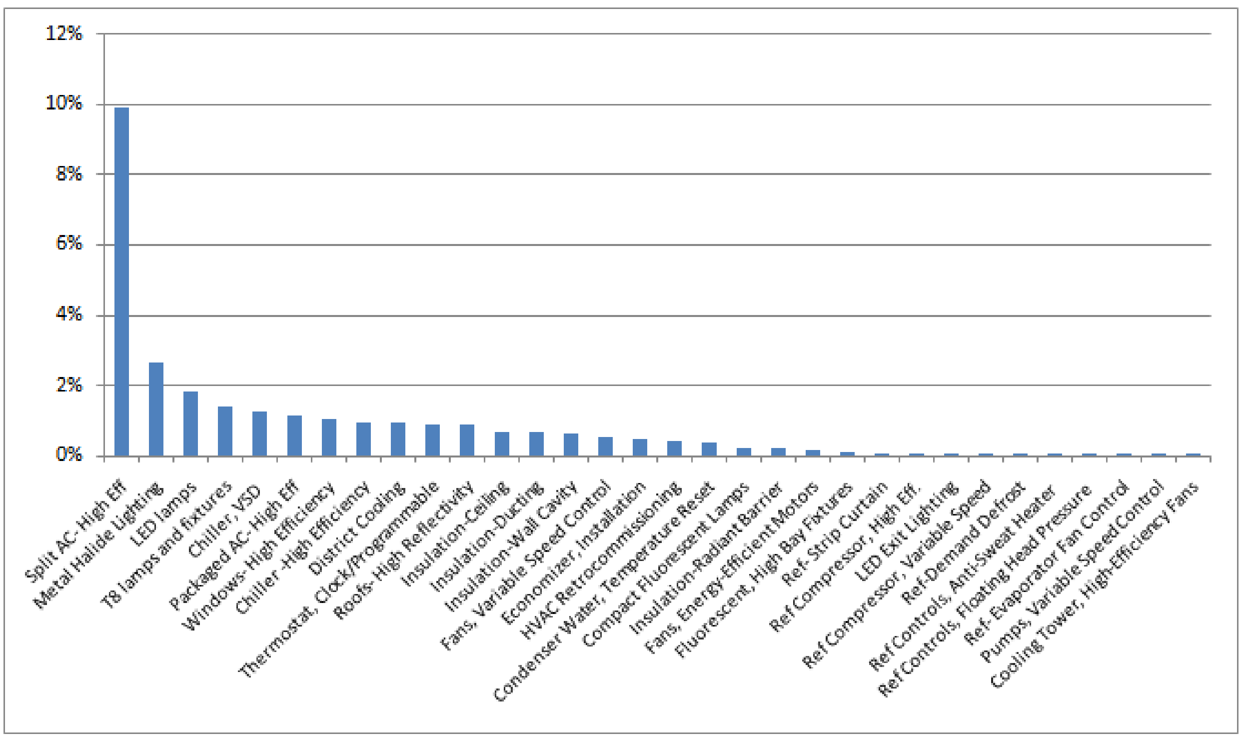

Figure 7-26: Commercial Sector Market Potential for EE (as % of commercial electricity use in 2012)

Energy efficiency measures for refrigeration systems are likely to have relatively low potential for energy savings opportunities with high associated costs. Therefore, they are unlikely to be targeted for drawing energy savings from the commercial sector in the near term. Among the building shell measures considered in our analysis, primarily for new construction, the largest amount of energy savings potential is associated with high efficiency windows (savings potential close to 1% of the commercial sector electricity use in 2012). However, this measure is not cost-effective even under shadow price conditions. High reflectivity roofs, which is cost-effective under shadow price conditions, also offers close to 1% energy savings potential of the commercial sector electricity use in 2012. The different types of insulation measures combined have a savings potential of slightly greater than 2% of the commercial sector electricity use in 2012. However, recall that none of these measures are cost-effective even under shadow price conditions.

Figure 7-27 presents the peak demand savings potential associated with the commercial energy efficiency measures in 2012. Figure 7-28 represents the potential as percentage of the commercial peak demand in 2012. Cooling and lighting measures combined have a potential to reduce commercial sector peak by more than 15% in 2012. Among cooling measures, the highest demand savings potential is associated with higher efficiency Split AC units, which could reduce commercial demand by 9%. Among lighting measures, metal halide and LED lamps along with T8 lamps and fixtures could reduce commercial demand by 5%. Moderate levels of peak demand savings potential are associated with a few of the building shell measures such as duct insulation, high efficiency windows, and high reflectivity roof. Higher efficiency windows and high reflectivity roofs could bring down demand by 1% each.

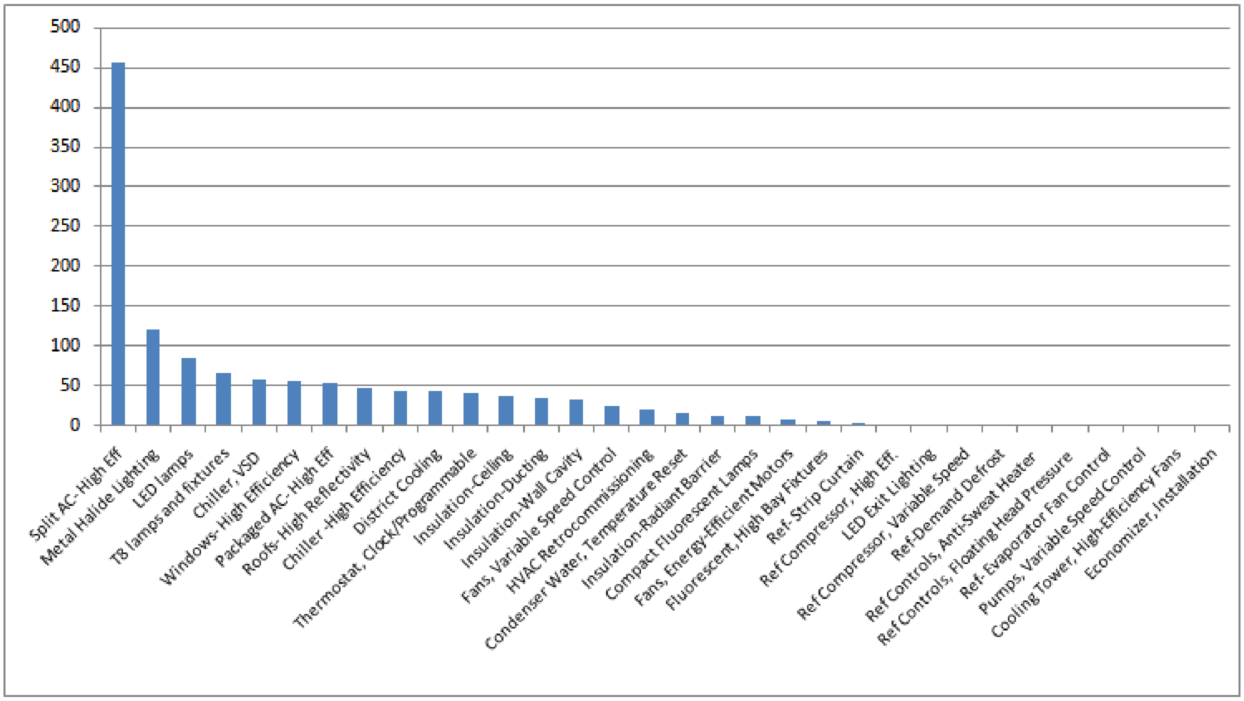

Figure 7-27: Market Potential for Commercial EE Measures in 2012 (MW)

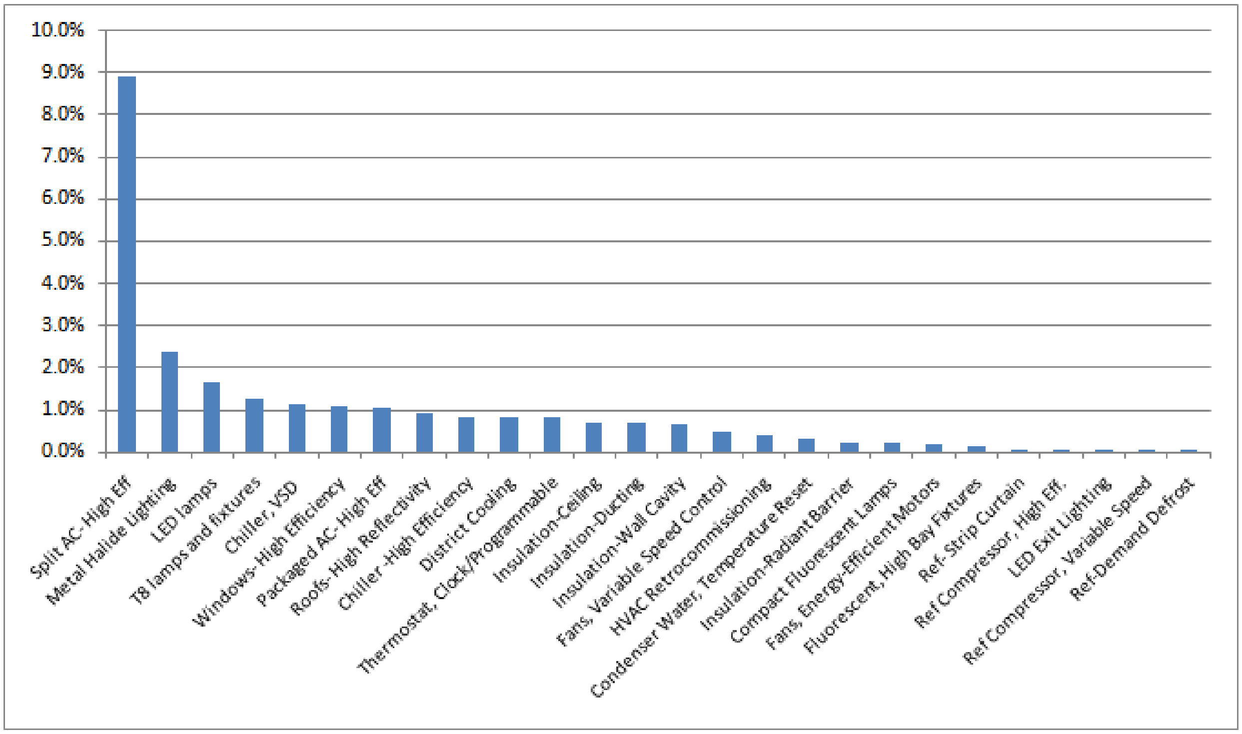

Figure 7-28: Commercial Sector Market Potential for EE (as % of commercial peak demand in 2012)

C. EE Measure Potential by Operating Area

Due to differences in the commercial customer mix, peak load, and sales in each operating area, EE measure potential tends to vary geographically. Figure 7-29 illustrates the allocation of each measure's potential by operating area.

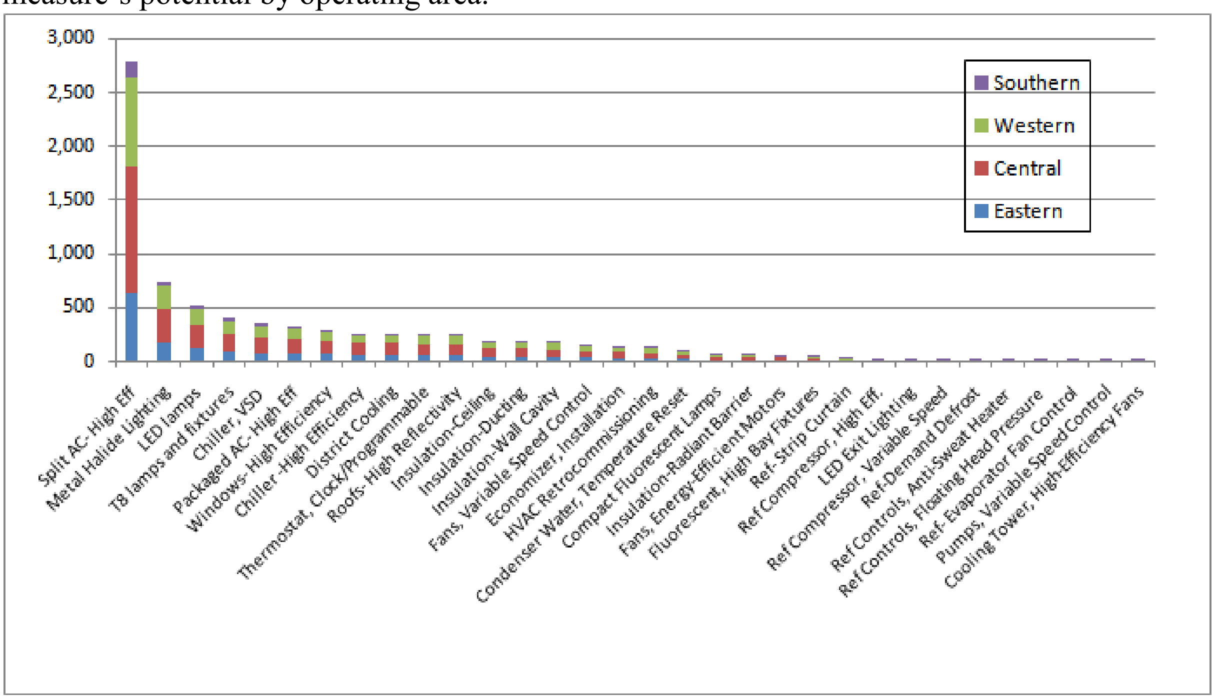

Figure 7-29: Commercial Sector Market Potential for EE by Region in 2012 (GWh)

The vast majority of the commercial sector potential is in the Central and Western operating areas, which is where most of the country's commercial customers are located. Unlike residential, the Central region has the highest share in potential savings from commercial energy efficiency measures, followed by the Western region. The Central region has more than 40% share, with the Western region coming second at 29% share. Eastern region's share is at 23%, with the remaining 6% coming from the Southern region.

D. Growth in EE Measure Potential over Time

As the commercial population and sales grow, the potential impact of each measure will grow as well. At the system level, this can be quite significant, with the potential impact of the measures growing by more than 65 percent over the next decade. Figure 7-30 illustrates the increase in measure potential between 2011 and 2021.

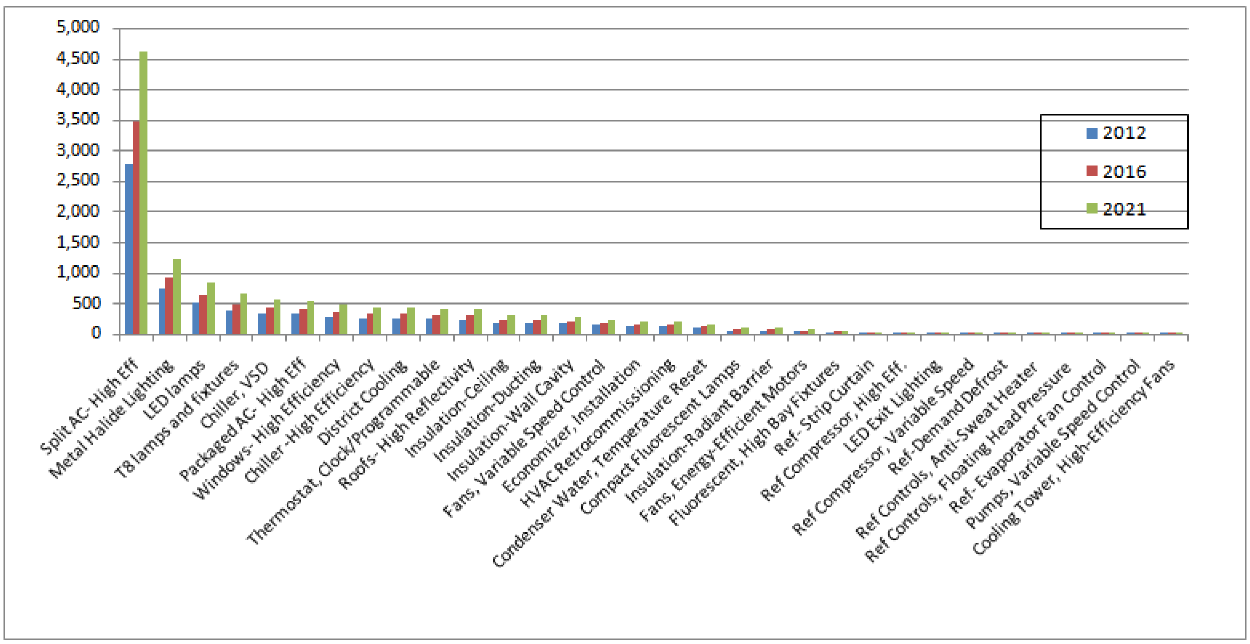

Figure 7-30: Commercial Sector Market Potential for EE by Year (GWh)

<u>Government Sector EE Market Potential</u>

A. Approach for Estimating Government Sector Market Potential

The approach taken to arrive at the government sector market potential is very similar to the one adopted for the commercial sector. First, the technical potential for each measure was estimated, drawing on the unit savings data for the measure. The technical potential associated with a measure indicates the maximum amount of potential associated with a measure, irrespective of cost-effectiveness of the measure, and assuming 100% participation rates. It represents an upper bound on the potential and is a theoretical concept.

Table 7-14 lists the assumptions used for scaling up unit measure level savings to the aggregate technical potential estimation for the entire government sector. Savings at the unit measure level are expressed in terms of per square footage. Therefore the average square footage for a typical building to which the measure applies is used as a scaling up factor.

The market potential estimation assumes that only a certain percentage of the market will adopt those measures that are cost-effective. The market potential estimates take into account factors related to market acceptance and program implementation. These factors serve to estimate the portion of the market that might potentially participate in future EE programs. Table 7-15 summarizes the market acceptance rates that were applied to the eligible customer segment in order to come up with Kingdom-wide levels of market potential for each of the government sector EE measures.

As an example, for Packaged AC units, the aggregate technical and market potentials were derived using the following formulae:

Aggregate technical potential for Packaged AC units = Annual kWh savings per square foot of building floor area from Packaged AC units * Average square feet for applicable building type (in this case typical medium size building) * Applicability Factor (based on % of buildings suitable for this measure) * Total number of commercial customers

Aggregate market potential for central cooling = Aggregate technical potential for Packaged AC units * Market acceptance and Implementation factor

Table 7-14: Scaling-Up Assumptions for Government Sector EE Measures

End-Use	Energy Efficiency Measure	Applicable building size	Average square footage for applicable building type (except Streetlighting and Pumping measures)	Applicability Factor (based on percent of buildings suitable for this measure)
Cooling	Split AC- High Eff	typical small size bldg	12,500	70%
Cooling	Packaged AC- High Eff	typical medium size bldg	62,500	15%
Cooling	Chiller -High Efficiency	typical large size bldg	125,000	10%
Cooling	District Cooling	typical large size bldg	125,000	5%
Cooling	Chiller, VSD	typical large size bldg	125,000	10%
Cooling	Cooling Tower, High-Efficiency Fans	typical large size bldg	125,000	10%
Cooling	Condenser Water, Temperature Reset	typical large size bldg	125,000	10%
Cooling	Economizer, Installation	typical large size bldg	125,000	10%
Ventilation	Fans, Energy-Efficient Motors	typical large size bldg	125,000	10%
Ventilation	Fans, Variable Speed Control	typical large size bldg	125,000	10%
Cooling	HVAC Retrocommissioning	typical large size bldg	125,000	10%
Cooling	Pumps, Variable Speed Control	typical large size bldg	125,000	10%
Cooling	Thermostat, Clock/Programmable	typical small size bldg	12,500	70%
Lighting	Compact Fluorescent Lamps	average for stock of all government buildings	37,000	50%
Lighting	Fluorescent, High Bay Fixtures	typical medium size bldg	62,500	15%
Lighting	T8 lamps and fixtures	average for stock of all government buildings	37,000	50%
Lighting	LED lamps	average for stock of all government buildings	37,000	10%
Lighting	LED Exit Lighting	average for stock of all government buildings	37,000	25%
Lighting	Metal Halide Lighting	typical medium size bldg	62,500	10%
Lighting	Municipal Streetlighting- Metal Halide	Total no. of lamps	2,875,000	45%
Lighting	Municipal Streetlighting- High Pressure	Total no. of lamps	2,875,000	45%
Lighting	Municipal Streetlighting- LEDs	Total no. of lamps	2,875,000	10%
Other	Municipal Pumping	Total HP of motors	745,600	75%
Building shell	Insulation-Ceiling	average for stock of all government buildings	37,000	70%
Building shell	Insulation-Ducting	average for stock of all government buildings	37,000	70%
Building shell	Insulation-Radiant Barrier	average for stock of all government buildings	37,000	70%
Building shell	Insulation-Wall Cavity	average for stock of all government buildings	37,000	70%
Building shell	Roofs- High Reflectivity	average for stock of all government buildings	37,000	70%
Building shell	Windows- High Efficiency	average for stock of all government buildings	37,000	70%

Notes:

1. Assumptions related to average sq. footage for applicable building sizes based on estimation, depending on the applicable building type

2. Assumptions for Municipal Streetlighting measures- No. of streetlights in KSA based on data from the number of streetlights per capita from Cambridgeshire, England. Based on Cambridgeshire data, there are 57,500 streetlamps for a population of 550,000. This is used for estimating the number of streetlamps in KSA for a population of 25 million.

3. Assumptions for municipal pumping- Assumed 1000 MW of water pumping load in KSA, with 0.7456 HP per kW of pumping load.

Table 7-15: Market Acceptance Rates for Government Sector EE measures[110]

End-Use	Energy Efficiency Measure	Market Acceptance and Implementation Factors (%)
Cooling	Split AC- High Eff	38%
Cooling	Packaged AC- High Eff	38%
Cooling	Chiller -High Efficiency	38%
Cooling	District Cooling	38%
Cooling	Chiller, VSD	38%
Cooling	Cooling Tower, High-Efficiency Fans	38%
Cooling	Condenser Water, Temperature Reset	38%
Cooling	Economizer, Installation	38%
Ventilation	Fans, Energy-Efficient Motors	35%
Ventilation	Fans, Variable Speed Control	35%
Cooling	HVAC Retrocommissioning	38%
Cooling	Pumps, Variable Speed Control	38%
Cooling	Thermostat, Clock/Programmable	38%
Lighting	Compact Fluorescent Lamps	60%
Lighting	Fluorescent, High Bay Fixtures	60%
Lighting	T8 lamps and fixtures	60%
Lighting	LED lamps	60%
Lighting	LED Exit Lighting	60%
Lighting	Metal Halide Lighting	60%
Lighting	Municipal Streetlighting- Metal Halide	60%
Lighting	Municipal Streetlighting- High Pressure	60%
Lighting	Municipal Streetlighting- LEDs	60%
Other	Municipal Pumping	40%
Building shell	Insulation-Ceiling	23%
Building shell	Insulation-Ducting	23%
Building shell	Insulation-Radiant Barrier	23%
Building shell	Insulation-Wall Cavity	23%
Building shell	Roofs- High Reflectivity	23%
Building shell	Windows- High Efficiency	23%

110 Market acceptance rates derived from a report prepared jointly by Global Energy Partners and The Brattle Group, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

B. Energy Savings Potential for Government EE Measures

Following the approach outlined earlier for estimating the aggregate market potential associated with individual EE measures, Figure 7-31 presents these results for the government sector. Figure 7-32 presents the market potential results as a percent of government baseline use in 2012.

Similar to the commercial sector analysis, the government sector analysis considered broadly four types of cooling measures: Split AC systems, Packaged AC units, Central Chiller systems, and District Cooling units. Among these broad measure types, higher efficiency Split AC units offer the largest amount of savings potential. This potential constitutes almost 4.5% of the overall government sector electricity usage in 2012. Also recall that Split AC units are cost-effective under current levels of avoided energy costs in the KSA. Packaged AC units along with higher efficiency chillers, each offer 2% energy savings potential in 2012. District cooling systems offer almost 1% energy savings potential. For central chiller systems, energy efficiency improvement by installing Variable Speed Drive (VSD) on chillers is estimated to have an energy savings potential at 3% of energy use in 2012. Energy savings potential from all other cooling related measures is estimated to be less than 1% of the commercial sector use.

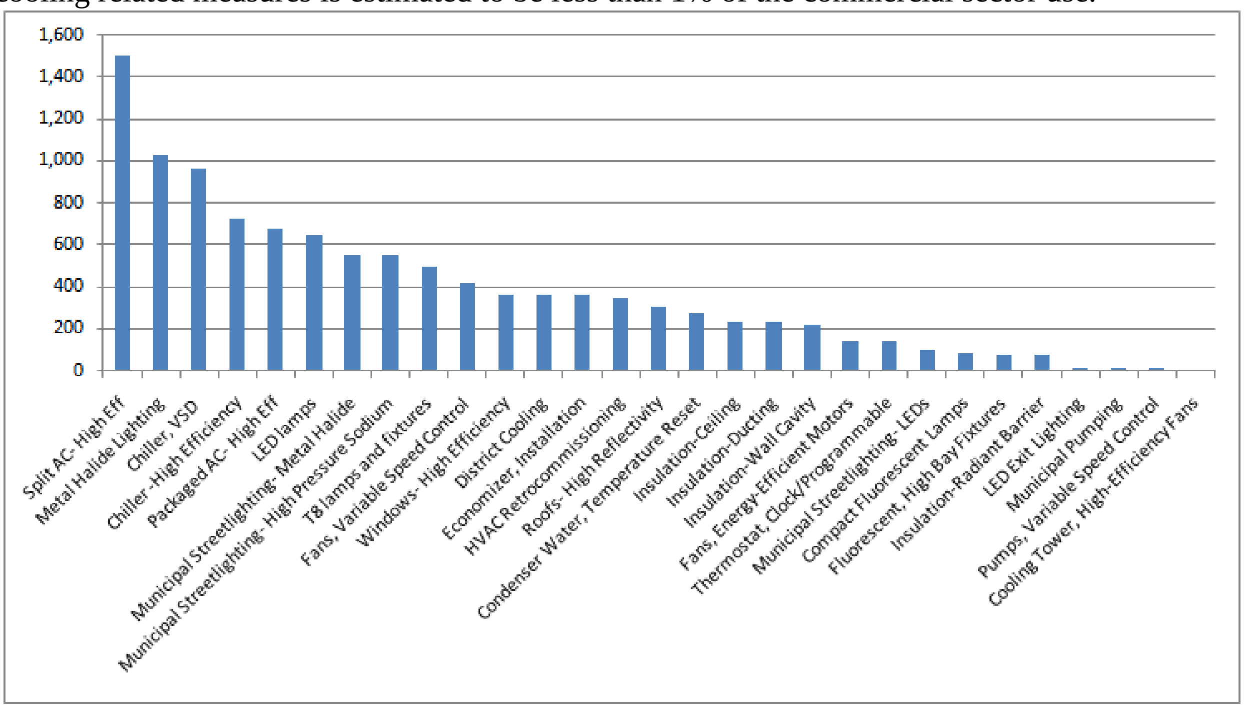

Figure 7-31: Market Potential for Government EE Measures in 2012 (GWh)

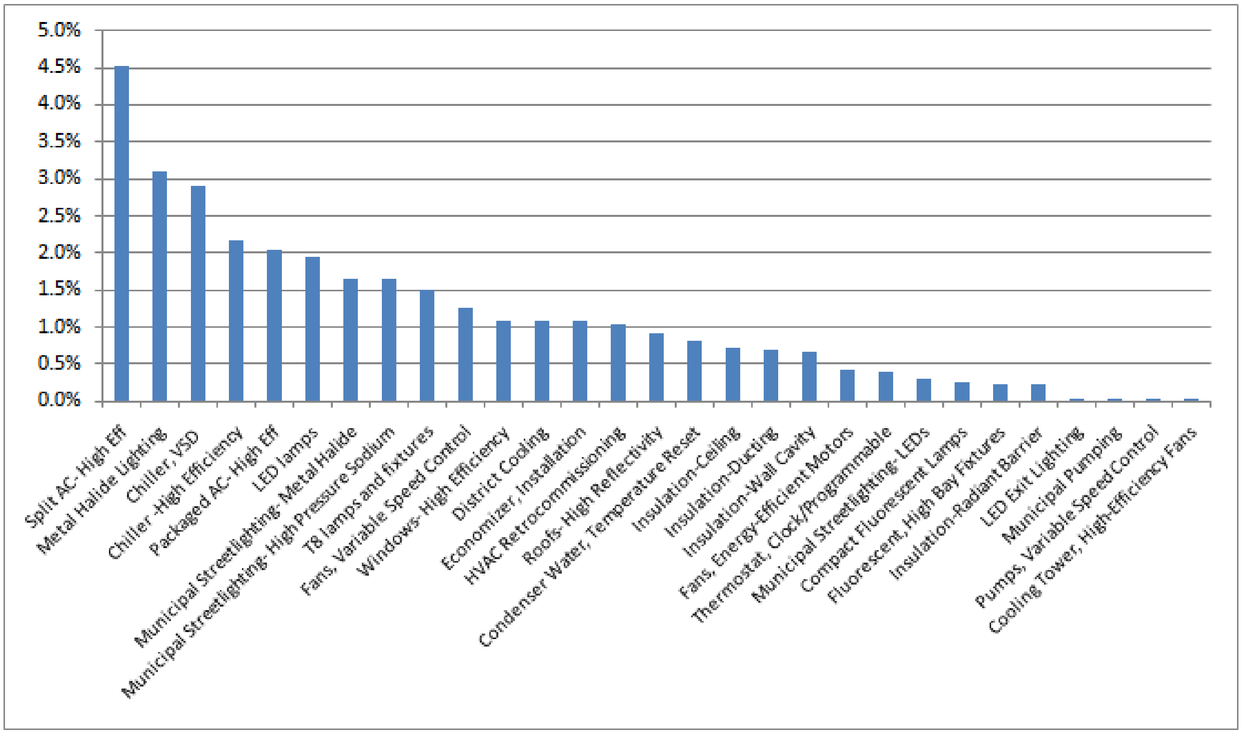

Figure 7-32: Government Sector Market Potential for EE (as % of government electricity use in 2012)

An interesting observation for the government sector is that all street lighting measures offer substantial energy savings opportunities. Recall that street lighting measures such as high pressure sodium and metal halide lamps are highly cost-effective even under current levels of avoided energy costs in KSA. Each of these measures has savings potential greater than 1.5% of the government sector electricity use in 2012. Among indoor lighting measures, metal halide lighting offers substantial energy savings opportunities at 3% of the government sector use in 2012. Also, LED lamps have close to 2% energy savings potential, followed by T8 lamps and fixtures at 1.5%.

Another measure specific to the government sector is municipal pumping, which is assessed to be cost-effective even under current levels of avoided energy costs in the Kingdom. However, the energy savings potential associated with this measure is extremely small. Building shell measures too have moderate to low levels of potential associated with them. Recall that none of the building shell measures are cost-effective under current levels of avoided energy costs in the Kingdom.

Figure 7-33 presents the peak demand savings potential associated with energy efficiency measures in 2012. Figure 7-34 represents the potential as a percentage of government sector peak demand in 2012. Not surprisingly, cooling measures with high levels of energy savings potential such as higher efficiency Split AC and Packaged AC units, along with central chiller improvements, also have the highest level of peak demand savings potential associated with them. Split AC systems, just by itself, could reduce demand by more than 4%. Among lighting measures, metal halide lamps offer more than 2.5% of demand savings opportunities. LED lamps along with T8 lamps and fixtures offer between 1.5-2% of demand savings opportunities. Street lighting measures using HPS and metal halide lamps could each reduce demand by more than

2%. Building shell measures such as higher efficiency windows, high reflectivity roofs, and different types of insulation measures have relatively low levels of demand savings potential ranging between 0.5-1%.

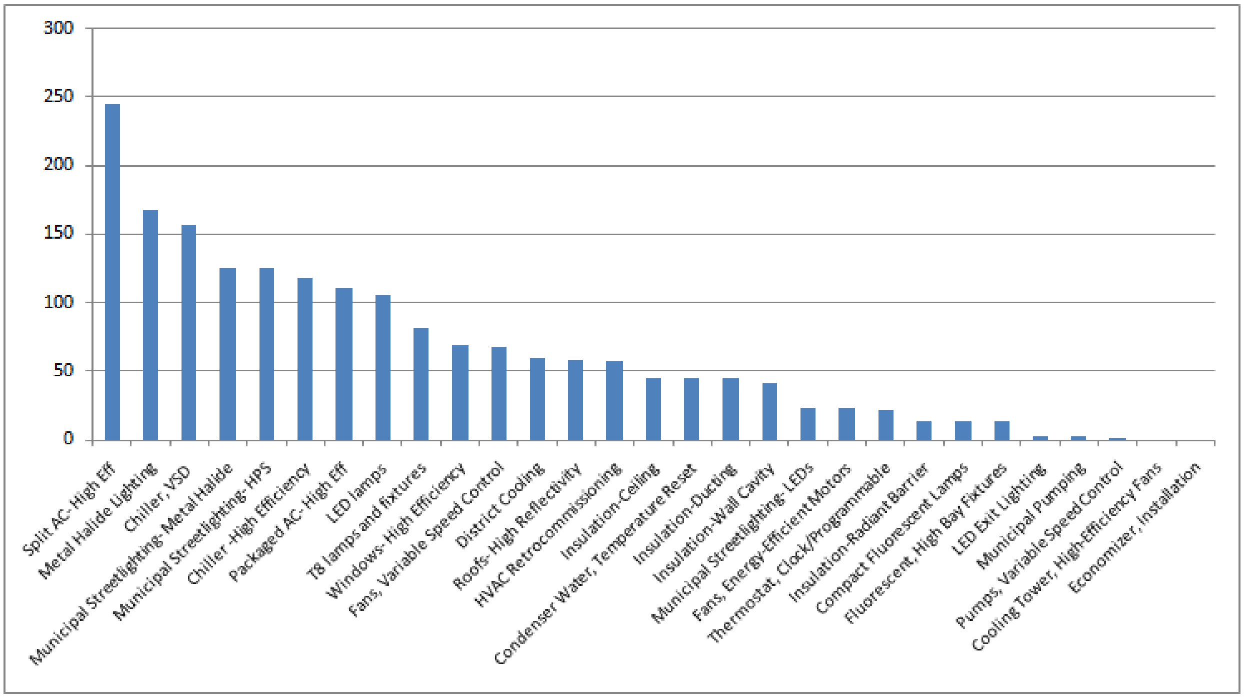

Figure 7-33: Market Potential for Government EE Measures in 2012 (MW)

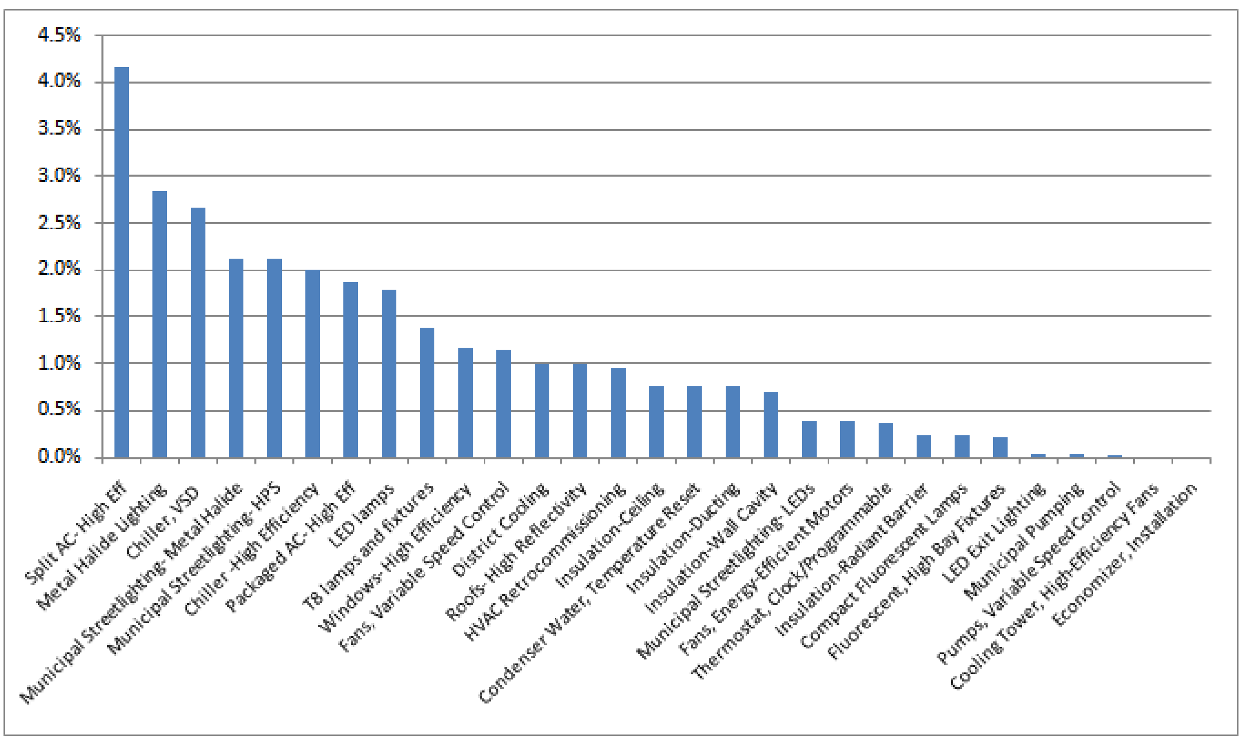

Figure 7-34: Government Sector Market Potential for EE (as % of government peak demand in 2012)

C. EE Measure Potential by Operating Area

Due to differences in the customer mix, peak load, and sales in each operating area, energy efficiency measure potential varies significantly by geographic region. Figure 7-35 illustrates the allocation of each measure's potential by operating area.

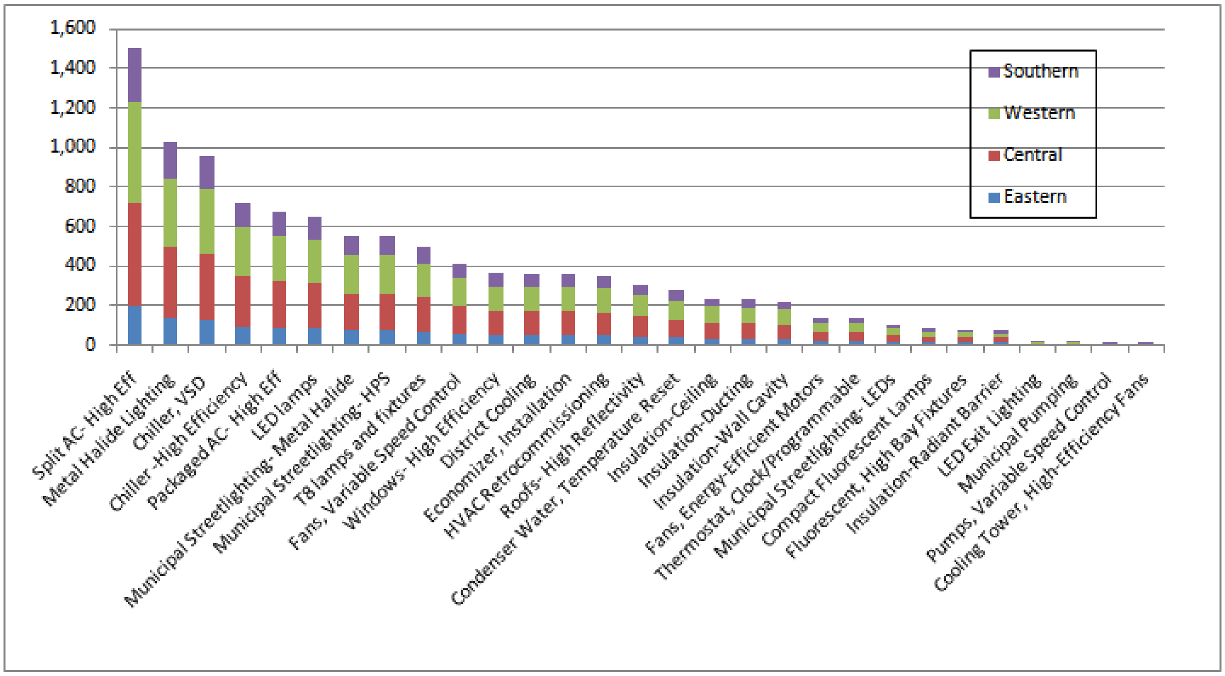

Figure 7-35: Government Sector Market Potential for EE by region in 2012 (GWh)

The Central and Western regions have an almost equal share in the potential from energy efficiency measures in the government sector, at a level of 34-35% of the overall market potential for the KSA as a whole. The Southern region has third largest contribution at 18%, while the remaining 13% is derived from the Eastern region.

D. Growth in EE Measure Potential over Time

As the government sector population and sales grow, the potential impact of each measure appears to be growing as well. At the system level, this can be quite significant, with the potential impact of the measures almost doubling over the next decade. Figure 7-36 illustrates the increase in measure potential between 2011 and 2021.

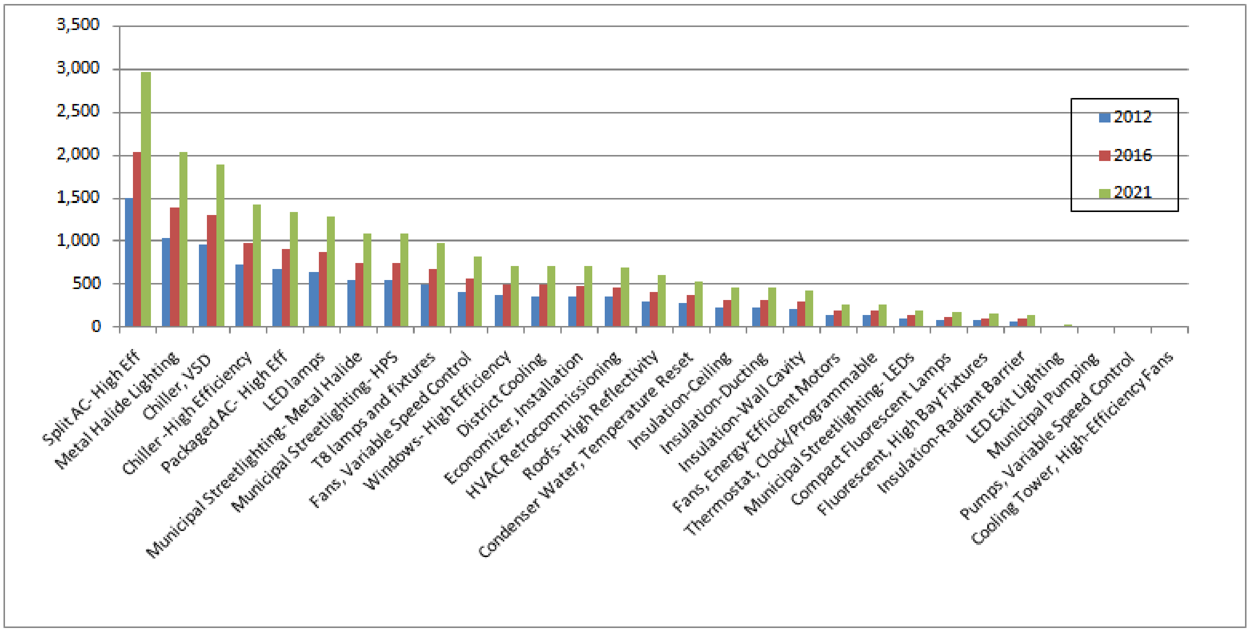

Figure 7-36: Government Sector Market Potential for EE by year (GWh)

Industrial Sector EE Market Potential

A. Approach for Estimating Industrial Sector Market Potential

The approach taken to arrive at the industrial sector market potential is similar to that described earlier for the other sectors. First, the technical potential for each measure was estimated, drawing on the unit savings data for the measure. The technical potential associated with a measure indicates the maximum amount of potential associated with a measure, irrespective of cost-effectiveness of the measure, and assuming 100% participation rates. It represents an upper bound on the potential and can be considered as a theoretical concept.

Table 7-16 lists the assumptions used for scaling up unit measure level savings to the aggregate technical potential estimation for the entire industrial sector. Energy savings potential for higher efficient motors is estimated in a top-down manner. Our baseline analysis shows that motors constitute almost 90% of the total industrial sector consumption. Based on experience from other studies, the average energy savings from industrial motors is estimated to be 13%[111]. Using these assumptions allows us to estimate energy savings potential from motors in the industrial sector.

[111] *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

Table 7-16: Scaling-Up Assumptions for Industrial Sector EE Measures[112]

End-Use	Energy Efficiency Measure	Unit	Applicable industrial facility size	Average square footage for applicable facility type	Applicability Factor (based on % of facilities suitable for the measure)
Cooling	Packaged AC- High Eff.	per total bldg. ft2	typical medium size facility	50,000	14%
Cooling	Chiller -High Efficiency	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	Chiller, VSD	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	Cooling Tower, High-Efficiency	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	Condenser Water, Temperature	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	Economizer, Installation	per total bldg. ft2	typical large size facility	100,000	50%
Ventilation	Fans, Energy-Efficient Motors	per total bldg. ft2	typical large size facility	100,000	50%
Ventilation	Fans, Variable Speed Control	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	HVAC Retrocommissioning	per total bldg. ft2	typical large size facility	100,000	50%
Cooling	Pumps, Variable Speed Control	per total bldg. ft2	typical large size facility	100,000	50%
Lighting	Compact Fluorescent Lamps	per total bldg. ft2	average for stock of all industrial facilities	25,000	50%
Lighting	Fluorescent, High Bay Fixtures	per total bldg. ft2	typical medium size facility	25,000	14%
Lighting	T8 lamps and fixtures	per total bldg. ft2	average for stock of all industrial facilities	25,000	50%
Lighting	LED lamps	per total bldg. ft2	average for stock of all industrial facilities	25,000	50%
Lighting	LED Exit Lighting	per total bldg. ft2	average for stock of all industrial facilities	25,000	50%
Lighting	Metal Halide Lighting	per total bldg. ft2	typical medium size facility	25,000	14%
Industrial	High Efficiency Motors	per HP	Total HP of motors	55,025,280	See Notes below

Notes

1. Assumptions related to average sq.footage for applicable facility types based on estimation, depending on the applicable facility size.

2. Assumptions related to high efficiency motors: Motors are assumed to represent 90% of industrial peak demand and energy consumption. Based on baseline data, the total industrial peak demand in KSA is 82 GW. This value is used to estimate the total HP of motors using a conversion factor of 0.7456 HP per kW. In order to estimate energy savings potential from motors, it is assumed that higher efficiency motors have a potential to reduce energy consumption by 13% (based on data from "Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S., Electric Power Research Institute. January 2009. (Report No. 1016987)").

The market potential estimation assumes that only a certain percentage of the market will adopt those measures that are cost-effective. The market potential estimates take into account factors related to market acceptance and program implementation. These factors serve to estimate the portion of the market that might potentially participate in future EE programs. Table 7-17 summarizes the market acceptance rates that were applied to the eligible customer segment in order to come up with Kingdom-wide levels of market potential for the industrial sector EE measures.

[112] Average square footage based on professional judgment. Applicability factors derived from Baseline conditions for the industrial sector (from Chapter 4), with measure-specific adjustments based on professional judgment.

Table 7-17: Market Acceptance Rates for Industrial Sector EE measures[113]

End-Use	Energy Efficiency Measure	Market Acceptance and Implementation Factors (%)
Cooling	Packaged AC- High Eff.	26%
Cooling	Chiller -High Efficiency	26%
Cooling	Chiller, VSD	26%
Cooling	Cooling Tower, High-Efficiency	26%
Cooling	Condenser Water, Temperature	26%
Cooling	Economizer, Installation	26%
Ventilation	Fans, Energy-Efficient Motors	26%
Ventilation	Fans, Variable Speed Control	26%
Cooling	HVAC Retrocommissioning	26%
Cooling	Pumps, Variable Speed Control	26%
Lighting	Compact Fluorescent Lamps	20%
Lighting	Fluorescent, High Bay Fixtures	20%
Lighting	T8 lamps and fixtures	20%
Lighting	LED lamps	20%
Lighting	LED Exit Lighting	20%
Lighting	Metal Halide Lighting	20%
Industrial Process	High Efficiency Motors	26%

B. Energy Savings Potential for Industrial EE Measures

Following the approach outlined earlier for estimating the aggregate market potential associated with individual EE measures, Figure 7-37 presents these results for the industrial sector Figure 7-38 presents the market potential results as a percent of industrial baseline use in 2012.

Savings from motors in 2012 is estimated to be 3% of the total industrial sector energy use. Savings opportunities from all other energy efficiency measures is considerably lower at less than 0.1% of industrial sector sales. Also, recall that higher efficiency motors for the industrial sector emerge nearly cost-effective (B/C ratio greater than 0.9) even under current avoided energy costs in the Kingdom. Therefore, this single area represents an extremely attractive opportunity for reaping substantial energy savings in the near term.

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[113] Market acceptance rates derived from study titled *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.*, Electric Power Research Institute. January 2009. (Report No. 1016987).

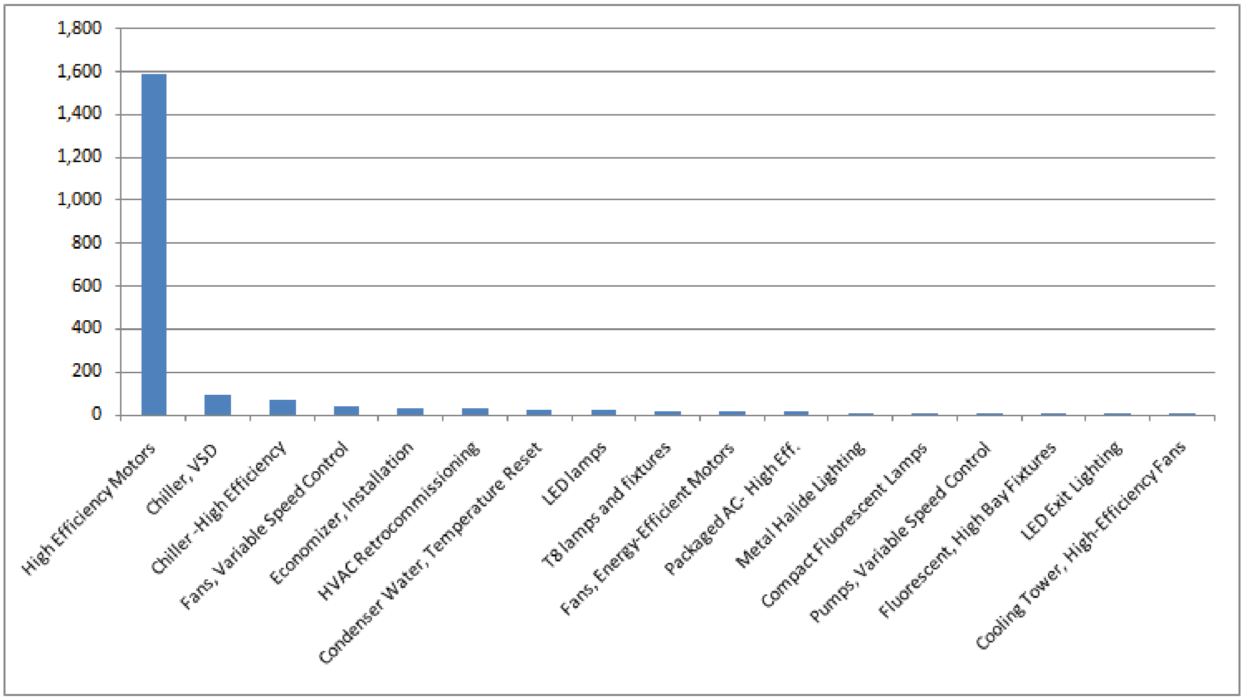

Figure 7-37: Market Potential for Industrial EE Measures in 2012 (GWh)

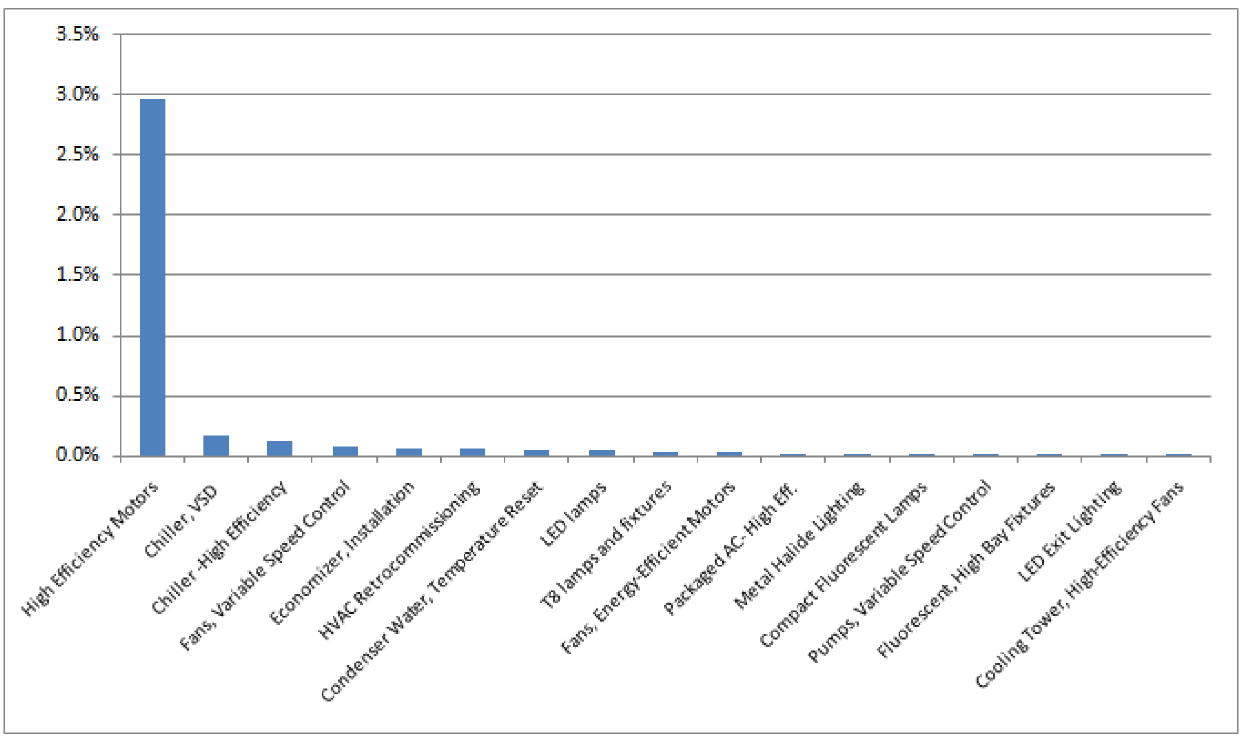

Figure 7-38: Industrial Sector Market Potential for EE (as % of industrial electricity use in 2012)

Figure 7-39 presents peak demand savings potential associated with energy efficiency measures in 2012. Figure 7-40 represents the potential as percentage of industrial sector peak in 2012.

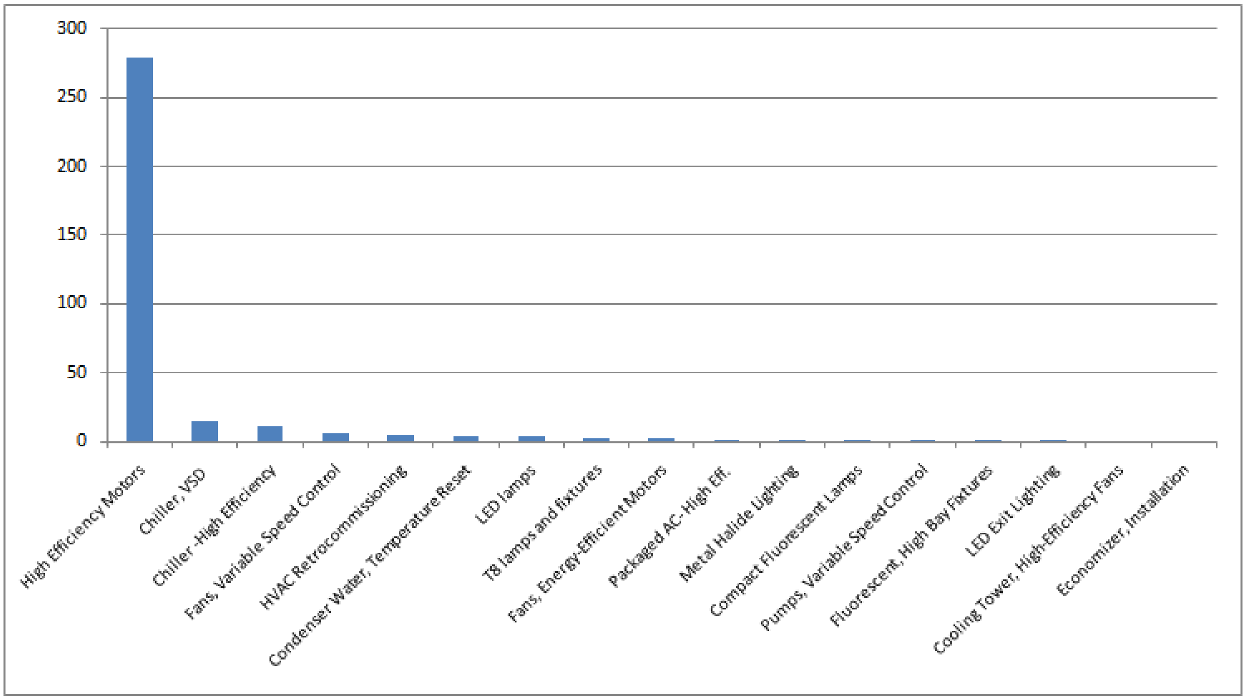

Figure 7-39: Market Potential for Industrial EE Measures in 2012 (MW)

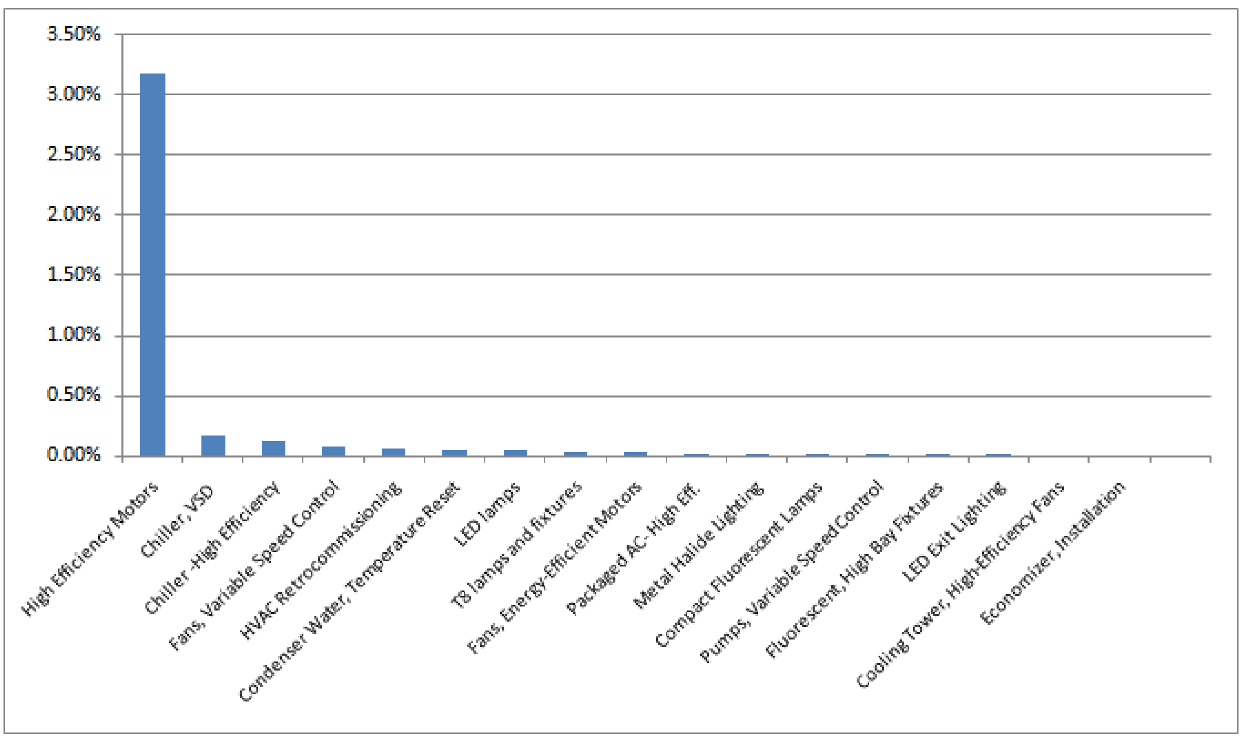

Figure 7-40: Industrial Sector Market Potential for EE (as % of industrial peak demand in 2012)

Similar to the results for energy savings, energy efficient motors too represent the largest amount of demand savings potential in the industrial sector. The aggregate demand reduction potential from industrial motors is estimated to be 3% of the overall industrial sector demand in 2012.

C. EE Measure Potential by Operating Area

Due to differences in the customer mix, peak load, and sales in each operating area, energy efficiency measure potential varies significantly by geographic region. Figure 7-41 illustrates the allocation of each measure's potential by operating area.

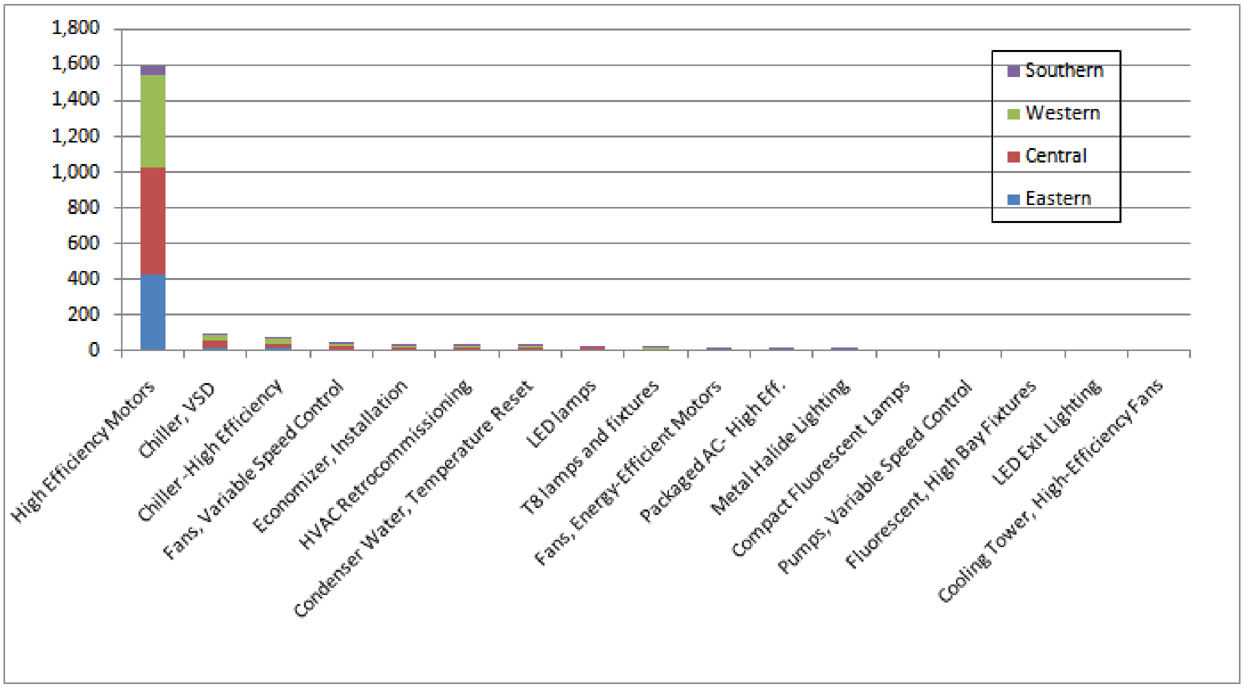

Figure 7-41: Industrial Sector Market Potential for EE by Region in 2012 (GWh)

Among the four regions, the central region has the largest share in the national potential at 37%, followed closely by the western region at 33%. The eastern region come third with 27% contribution, while the Southern region ranks lowest at only 3% of the national potential.

D. Growth in EE Measure Potential over Time

As the industrial sector population and sales grow, the potential impact of each measure appears to be growing as well. At the system level, this can be quite significant, with the potential impact of the measures almost doubling over the next decade. Figure 7-42 illustrates the increase in measure potential between 2011 and 2021.

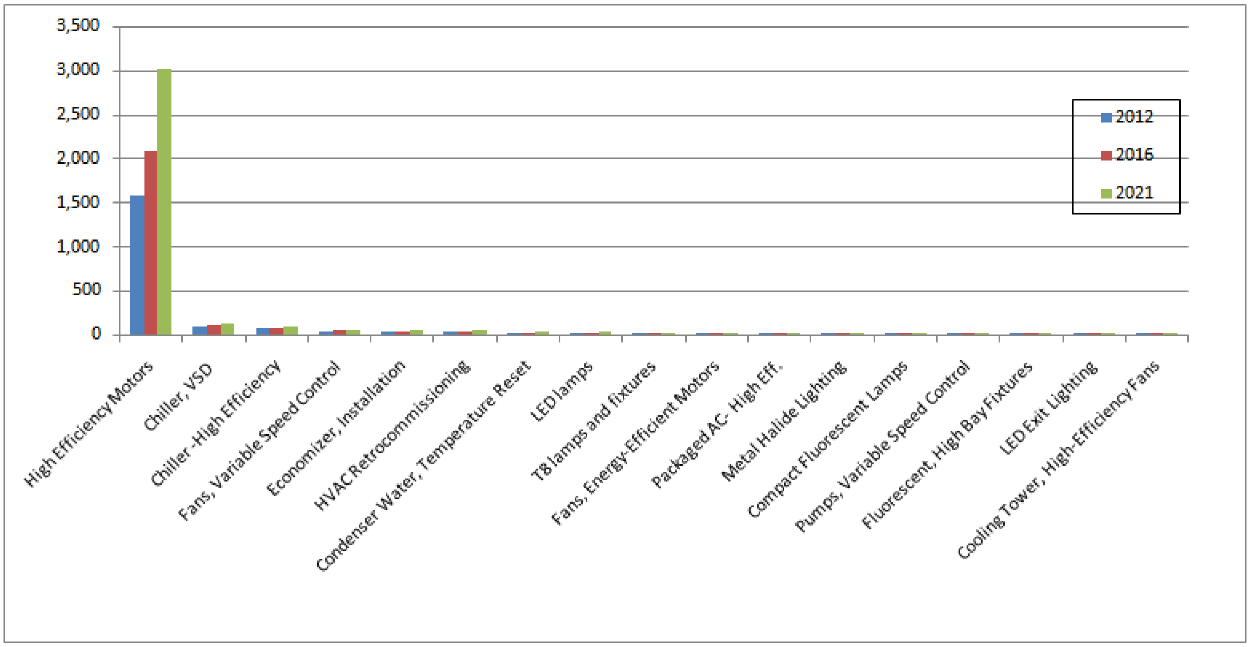

Figure 7-42: Industrial Sector Market Potential for EE by year (GWh)

7.2.4. EE Implications for the KSA

The results of the economic screening and market potential assessments can be combined to inform decisions about how best to pursue EE opportunities in the KSA. Measures with large market potential and benefit-cost ratios significantly greater than 1.0 are ideal candidates for EE programs and should be considered for implementation in the near term.[114] Measures with small market potential or that are clearly unattractive from an economic perspective are less likely to be successful, at least in the near term, and should be given lower priority in a Kingdom-wide rollout of energy efficiency programs. In Figure 7-43, each measure is characterized according to its market potential size and benefit-cost ratio.

[114] Note that the cost-effectiveness tests are very dependent on avoided energy costs. Since the actual avoided energy costs in the KSA are substantially below market rates, it is likely that many measures are failing the B/C tests where they normally would be considered under normal market conditions.

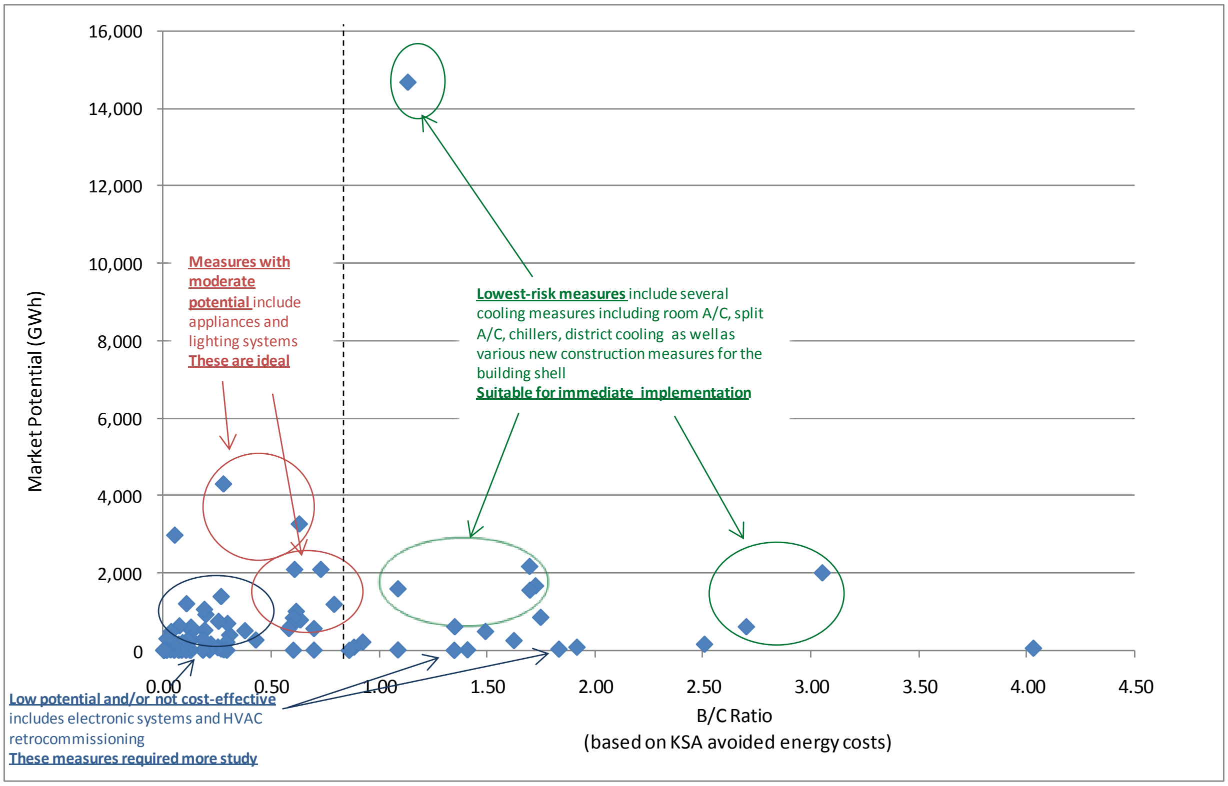

Figure 7-43: Potential Measure Impact and Benefit-Cost Ratio (2012)

The figure identifies three likely implementation scenarios for energy efficiency measures. First is the category of "low-risk measures". These measures tend to have substantial market potential and are very cost-effective, even with the KSA-specific avoided energy costs. They would be ideal candidates for immediate implementation. The second category represents measures with moderate market potential, and generally would be cost-effective using market-based avoided energy costs. These measures might be suitable for pilot implementation in the short- to medium-term. The third category represents measures that have very low market potential and are clearly not cost-effective. These measures would require more study to better understand the market conditions that might make them more attractive to consumers in the future. Several implications can be drawn from this comparison of EE measures:

<u>Near-term implementation.</u> There are several EE measures that can be grouped right away into various energy efficiency programs. These measures include:

- Residential cooling measures (high efficiency Split and Central A/C systems, room A/C and programmable thermostats) show some of the highest market potential and are very cost-effective. High efficiency Room A/C units alone offer more than 14,000 GWh of energy savings potential in 2012, which translates to 12% of residential electricity sales in the KSA.
- Commercial and government cooling measures (high efficiency packaged A/C, central chillers and district cooling) show significant potential and tend to be cost-effective under market-based prices.

- Residential building shell measures (ceiling insulation, wall insulation and windows) have the potential to yield significant savings (over 4,000 GWh or close to 3% of overall residential electricity sales).

These are low risk measures with considerable amount of international implementation experience, and could be targeted right away for reaping substantial benefits in the short-term.

<u>Medium-term implementation.</u> Some of the measures that were not cost-effective according to KSA-specific avoided energy costs but are highly cost-effective according to market-based avoided energy costs. These measures include:

- High efficiency appliances for the residential sector (refrigerators, freezers, clothes washers and dishwashers).
- High efficiency lighting systems applicable to all sectors include high pressure sodium, high-bay fluorescent and possible T8 lamps and ballasts.[115]
- High efficiency water pumping for the government sector is not expected to yield significant savings but appears to be nearly cost-effective.[116]
- Streetlighting measures for the government sector will yield significant savings (over 1,100 GWh or 3% of total government electricity sales).

<u>Long-term implementation.</u> These are measures that were either clearly not cost-effective or did not show significant market potential. The drivers for these measures typically relate to the relatively high first cost due to their experimental nature. It is recommended that these measures be considered for implementation at a later date when more information is available and potential markets are created in other parts of the world such that the measure cost is ultimately reduced due to scale economies being experienced.

<u>KSA-specific end-use data is limited and needs to be enhanced.</u> Because of the limited KSA data on energy use and peak demand by market segment and end-use, it is difficult to identify potential niche areas of opportunity for EE savings. Therefore it is recommended that more data that are specific to the KSA be collected that will ultimately enhance the future efforts to screen prospective EE measures.

[115] Note that T8 lamps and ballasts did not appear to be as cost-effective or yield as much savings as would be expected in other parts of the world. This is an area that requires further investigation.

[116] Savings estimates may be higher once further data about this sector is revealed in future studies.

8. CREATING DSM PROGRAMS

The economic assessment of each DSM measure has helped to identify those that are most attractive for deployment in the KSA. The next step is to group those measures into programs that can be offered to customers. Measures are grouped into programs in order to take advantage of economies of scope and scale through a coordinated implementation effort. This has practical advantages over trying to manage each measure separately.

The process of developing DSM programs involved a multi-faceted approach that is illustrated in Figure 8-1. The figure depicts the information flow that was used by the *Brattle* team for consolidating all of the elements that served as inputs toward ultimately developing the DSM programs.

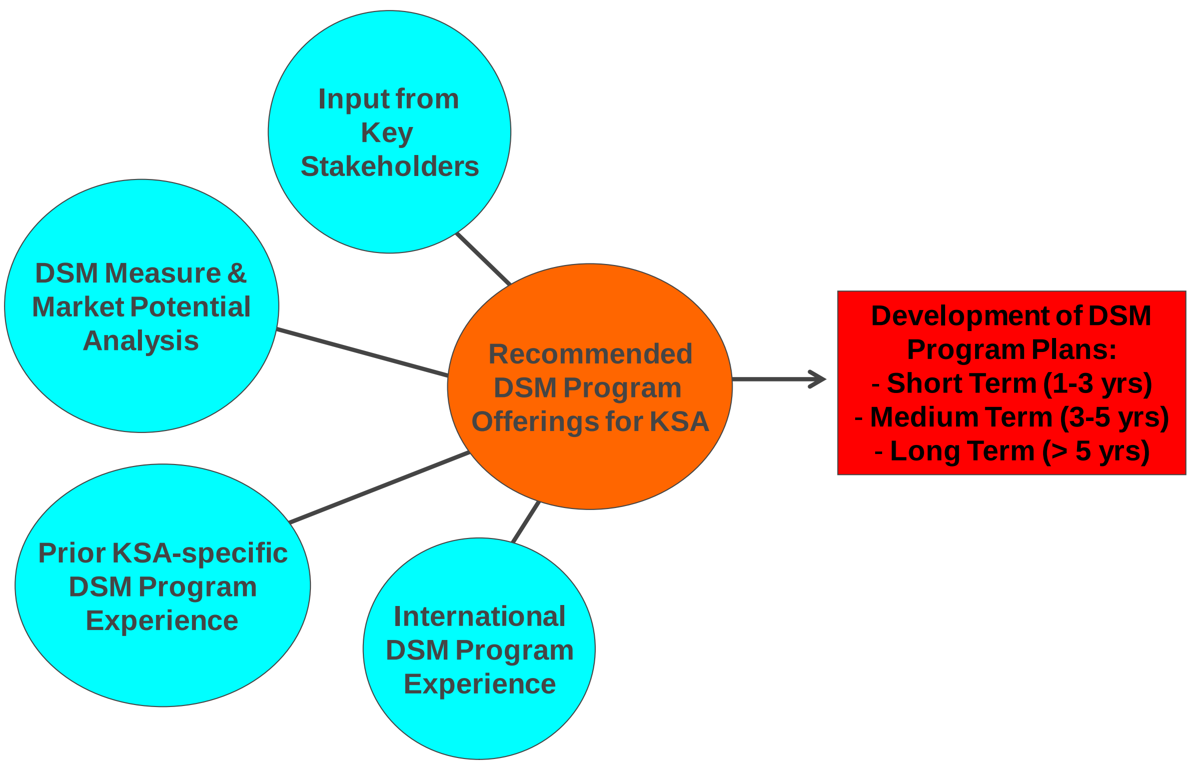

Figure 8-1: DSM Program Plan Development Process

There are a number of important information sources that were evaluated during the process of formulating the recommended DSM program offerings described in this chapter:

- ***DSM Measure and Market Potential Analysis:*** The types of DSM measures evaluated and the magnitude of DSM market potential savings were major consideration in the program development process. For each segment and end-use market, the *Brattle* team reviewed the measures that passed the amount of achievable potential which might be obtained through programs. The results of the market potential ultimately guided the program development resources toward those segments and end-use markets that appeared to provide the greatest level of cost-effective savings. See Chapter 7 for details.

- ***Past KSA Program Experience:*** This experience came from a variety of DSM programs and initiatives that have been implemented by various entities within the KSA. The *Brattle* team reviewed the various attributes of those programs to determine which elements might be applicable and transferable to the conditions and characteristics that best define where the KSA is currently.
- ***International DSM Program Experience:*** A vast amount of information is available from a number of countries in terms of the best practices for DSM programs. The *Brattle* team reviewed this information and brought many of the applicable elements together in order to represent the types of DSM programs that might work best in the KSA.
- ***Stakeholder Process:*** Over the course of developing this study, the *Brattle* team held a number of meetings with key stakeholders in the KSA. The stakeholders represent a broad constituency of parties interested in the implications of future DSM program offerings. They include representatives from governmental agencies, utilities, academia, and industry. The stakeholders provided valuable insights into the various DSM measures and types of programs that could be recommended as part of this Plan. Many of those recommendations are represented in the programs that are presented here.

The next sections describe the groupings of measures that are being recommended for implementation as DSM programs in the KSA.

8.1. Recommended LM/DR Measures for Plan Development

The recommended LM/DR measures are summarized by customer segment in Table 8-1.

Table 8-1: Recommended LM/DR Measures

	Best candidates for short-term deployment (low-risk with significant potential)	**Best candidates for medium-term deployment** (attractive but some uncertainty around impacts or likely acceptance)	**Measures requiring further analysis** (could be considered for long-term as technology matures or market economics change)
Residential	DLC (for large customers with central A/C)	Pricing measures with and without enabling tech (i.e. PCT); information measures	None identified
Commercial	Interruptible tariffs; DLC[1]	Pricing measures with and without enabling tech[2]	Thermal energy storage; other storage
Government	Interruptible tariffs; DLC[1]	Pricing measures with and without enabling tech[2]; water pumping	Thermal energy storage; other storage
Industrial	Interruptible tariffs; Curtailable load management	Pricing measures with or without Auto-DR	Thermal energy storage; other storage

Notes:
(1) Government DLC measures are economically attractive and although lower volumes than the residential sector, can be applied to buildings such as mosques, schools, and ministries. They are included as candidates for short-term deployment since pilot programs have already been implemented in the KSA. Commercial participation in DLC programs is expected to be limited to very specific sub-segments of customers (e.g., small retail, office, etc.).
(2) Note that pricing measures were not found to be cost-effective for the commercial and government segments; However, if smart metering is deployed for these segments, then the cost of offering these rate options is minimal

Measures ready for short-term deployment have low financial risk (i.e. a high benefit-cost ratio) and significant load curtailment potential. These are measures which the appropriate entities in the KSA could immediately begin to develop and implement as programs on a large scale. Key features of these measures are provided below.

Direct load control (DLC)

- Significant potential due to large contribution of air-conditioning load to peak demand
- Air-conditioner is controlled with a switch that is installed on the unit outside the building (i.e. does not require entry into the home for installation and maintenance)
- Residential program would focus on large customers with central air-conditioning, because this is the most common and proven application of DLC[117]
- SEC's DLC pilot for commercial and government customers has already provided the KSA with significant experience in offering the program to those segments
- Voluntary participation reduces risk of customer backlash

[117] In the future, due to the large share of air-conditioning that is in window units and split systems, it could be desirable to explore options for expanding the DLC program to include these forms of air-conditioning.

Interruptible Tariffs / Curtailable Load Management

- These programs are offered by many utilities and are among the most common LM/DR options around the globe
- These programs have achieved very large peak load reductions due to the effectiveness of their payment/penalty incentive structure
- The cost of offering these measures to industrial customers is very low, because most customers will already be equipped with the necessary interval metering technology

Measures for medium-term deployment are attractive from the perspective of their economics and potential peak impact. However, these measures have a greater degree of uncertainty around their likely acceptance or feasibility in the KSA. These are measures that should also be pursued in the KSA, but with a slower deployment schedule and additional market research.

Time-based Pricing

- Includes TOU pricing and dynamic pricing (e.g. critical peak pricing and peak time rebates)
- These rate designs should first be tested through controlled trials to determine customer response and acceptance rates; this would help to identify the best option(s) for large scale deployment
- Offering these rates would first require that customers be equipped with smart meters
- Political barriers may exist to changing the tariff for the residential segment

Other Pricing Options

- Includes seasonal rates and demand charges
- Seasonal tariffs could be offered using the existing (electromechanical) meters
- KSA energy prices suggest that a price differential of more than 50% could be justified between the summer and winter seasons
- Demand charges would be appropriate for large commercial and industrial customers and would provide a monthly incentive to reduce peak demand
- These options could also be tested through controlled trials

Enabling Technologies

- These technologies help customers respond to time-based rates by automating load reductions during high-priced hours (e.g. a smart thermostat)
- Controlled trials are needed to better understand the incremental impacts of these technologies in the KSA and to refine the cost-benefit estimate
- Auto-DR is a promising option for some large commercial and industrial customers

Information Measures

- Includes in-home information displays, social norming, and web portals
- Only applicable to the residential segment

- These measures are cost effective based on customer response estimates from other regions, but controlled trials are needed to determine whether a similar response would be realized in the KSA

Water pumping

- An agreement with SWCC and NWC (National Water Company) could provide incentive payments for reductions in pumping load during peak times
- In the short-term, dialogue between SWCC, SEC, and ECRA should be initiated to determine the feasibility and likely impact of this measure

Several additional measures were identified as having load curtailment potential in the KSA. However, these measures are either not likely to be cost-effective, or would require significant additional research before implementation.

Thermal energy storage

- This measure is not found to be cost-effective from a societal perspective in the KSA (i.e. the capital cost of SR 7,500/kW is too expensive relative to other options)
- However, there may be project-specific applications in which it would be cost-effective (e.g. to reduce the roof space requirement for A/C units or to reduce the size of the network connection in new construction)
- It should be re-evaluated in five years to determine the extent to which changes in technology costs or system dynamics may change this conclusion

Other storage options

- Other storage options, such as battery storage, have future potential but are not cost-effective at today's technology costs

8.2. Recommended EE Measures for Plan Development

The recommended EE measures are summarized by customer segment in Table 8-2.

Table 8-2: Recommended EE Measures

Sector	**Best candidates for short-term deployment** (low risk with significant potential)	**Best candidates for medium-term deployment** (attractive but some uncertainty around impacts or likely acceptance)	**Measures requiring further analysis** (could be considered for long-term as technology matures or market economics change)
Residential	Cooling measures; New buildings	Appliances; Lighting measures	Home electronic equipment
Commercial	Cooling measures; New buildings	Lighting measures	Office electronic equipment; HVAC retrocommissioning
Government	Cooling measures; New buildings	Lighting measures	Office electronic equipment; HVAC retrocommissioning; municipal water pumping
Industrial	None identified	None identified	Process efficiency, Motors, HVAC retrocommissioning

Similar to the LM/DR analysis, EE measures for short-term program deployment have low financial risk and significant energy savings potential. Key features of these measures are provided below. Further details pertinent to program costs (i.e., incentives and rebates) are covered in Chapter 12.

Cooling Measures

Because of the large amount of cooling required for the Kingdom and wide availability of high efficiency products on the worldwide market, there appears to be a significant amount of cost-effective energy efficiency potential. This would be an equipment replacement program designed to upgrade existing cooling equipment to higher levels of efficiency at the time when customers are in the process of replacing their cooling equipment due to failure or facility expansion. Incentives would be offered to the end-use customer in the form of cash rebates intended to offset some or all of the customer's incremental cost associated with the high efficiency measures. Other non-cooling measures would also be promoted as part of this program to improve public awareness of energy efficiency and bring about significant amounts of energy savings in the short-run. In parallel, minimum efficiency standards would be established through a compact between the KSA and cooling equipment manufacturers and distributors such that they would be required to supply a minimum level of efficiency but offered an incentive if they supply higher levels of efficiency. [118]The cooling measures would be applicable for all four customer segments in the KSA. For the residential sector, three equipment types would be included as part of the program:

[118] Existing residential cooling equipment is assumed to be almost 8.0 EER and new/upgraded cooling equipment 10 EER (at 35 degrees Celsius). This equates to the SASO labeling standard for 2-Star and 5-Star, respectively. See Tables 7-5 to 7-8 for details.

- Room air conditioning units for small detached homes and apartments
- Split-system air conditioning units for medium and larger detached homes
- Central air conditioning systems for larger detached homes and villas
- Programmable thermostats

For commercial, government and industrial sectors, three equipment types would be included as part of the program:

- Split-system air conditioning units for offices, retail, government, mosques and industrial buildings
- Central chillers (air-cooled, water-cooled and variable speed) for large offices, large retail, hospitals, mosques, and large government buildings
- District cooling systems for commercial offices and retail complexes and large government campus facilities

New Buildings

This program would be designed to accelerate the incorporation of energy efficiency into the design, construction, and operation of new homes and buildings in the Kingdom. The program would be designed to reinforce and strengthen existing minimum building performance standards for wall and ceiling/roof insulation and high performance double-pane windows. Penalties would be imposed on builders and contractors for non-compliance with the minimum standards. In addition, the program would promote the design and inclusion of high efficiency cooling and lighting systems through financial incentives offered to builders and contractors who meet the building performance standards. For the residential sector, these energy efficiency measures would be applicable for the program:

- Building shell measures (ceiling and wall insulation, high efficiency windows[119])
- High efficiency cooling equipment (split-system and central AC units)

For the commercial and government sectors, these energy efficiency measures would be applicable for the program:

- Building shell measures (duct and roof insulation)[120]
- High efficiency cooling equipment (split-systems and central chillers)
- District cooling systems for commercial offices and retail complexes and large government campus facilities

For the industrial sector, it was concluded that no energy efficiency measures would be applicable for this program. This decision was based on the fact that cooling loads make up a very small share of the industrial loads.

Measures for medium-term deployment should also be pursued in the KSA, but with a slower deployment schedule and additional market research.

[119] Note that high efficiency windows do not appear to be cost-effective but are included nonetheless as they can be packaged with more cost effective measures in the program.

[120] Note that these building shell measures do not appear to be cost-effective but are included nonetheless as they can be packaged with more cost effective measures in the program.

Appliances[121]

- A bounty program would be established with equipment manufacturers providing incentives to offer high efficiency products for sale in the KSA
- The program would be targeted exclusively towards residential appliances
- The extra costs for these measures would be offset by point-of-sale rebates and other cost buy-down incentives such as coupons
- The types of appliances would encompass refrigerators, dishwashers and clothes washers
- These options could also be tested through controlled trials and pilot tests in selected locations in the KSA

Lighting Measures

- A bounty program would be established with equipment manufacturers providing incentives to offer high efficiency products for sale in the KSA
- The extra costs for these measures would be offset by point-of-sale rebates and other cost buy-down incentives such as coupons for residential customers and equipment supplier discounts for lighting designers and other distributors of equipment to commercial, governmental and industrial customers
- These options could also be tested through controlled trials and pilot tests in selected locations in the KSA

Several additional measures were identified as having energy efficiency potential in the KSA. However, these measures are either not likely to be cost-effective, or would require significant additional research before implementation.

Home and Office Electronic Equipment

- Because of the standby nature of many modern electronic devices (such as computers, printers and TVs), a significant amount of energy is expended when the equipment is not operational (so-called shadow energy consumption)
- More investigation should be pursued to better understand whether electronic products offered in US and European markets that reduce shadow energy consumption could be offered in the KSA

HVAC Retrocommissioning

- Over time, the complex mechanical systems providing cooling to commercial, government and industrial spaces become mismatched to the loads they are serving as a result of deteriorating equipment, clogged filters, changing demands and schedules, and pressure imbalances.
- Retrocommissioning is a comprehensive analysis of an entire system in which an engineer assesses shortcomings in system performance, then optimizes through a process of tune-up, maintenance, and reprogramming of control or automation software.

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[121] Note that these measures are not cost-effective using KSA-specific avoided energy costs. However, when shadow avoided energy costs are applied, the measures appear to be more cost-effective.

- More investigation should be pursued to better understand whether retrocommissioning programs could be pursued in order to significantly reduce energy consumption in existing buildings

Municipal Water Pumping Efficiency

- Due to the large water pumping loads in the KSA, it would be appropriate to address potential inefficiencies in the municipal pumping systems within large cities. More data would be needed to gain a more accurate understanding of the current existing pumping loads and the potential for improvements to those loads through high efficiency measures.
- High efficiency motors for pumping appear cost-effective but appear to have limited market potential.[122] Controlled trials are needed to better understand the true size of the market for these measures

Process Efficiency, Motors

- Motors account for about 90% of the industrial electricity usage. There is a large potential for improving the energy efficiency of motors. Unfortunately, very little is known about the electricity usage for specific industries. More research is needed to better understand which industries might be better candidates for promoting high efficiency motors.
- While contained within the motors category, much of the electricity use in the industrial sector is attributable to very specific processes that are unique to that industry, and are many times unique to a particular plant or process. To most effectively capture the potential for process improvements, more primary research is needed in the form of industrial process audits and equipment inventories. Once well understood, a viable EE program could be developed.

Implementation plans for each of these programs are provided in detail in Chapters 12 through 14. The plans serve as a blueprint for the activities that would be needed to deliver these programs to customers.

[122] This conclusion is based on the limited KSA data that was available for this segment. In discussions with individuals at ECRA, it is believed that there is more energy use for this segment than was estimated in this study thus rendering this measure potentially feasible for future implementation.

9. BARRIERS TO DSM IMPLEMENTATION

Our analysis of DSM measures suggests that there is significant potential for cost-effective peak demand and energy reductions in the KSA. These measures could reduce hundreds or thousands of megawatts of load at a fraction of the cost of building new capacity. Given that the resulting financial benefits to the KSA could be billions of Riyals, this raises an important question: Why aren't these measures being implemented already?

Interviews with stakeholders identified several barriers that have kept DSM from being implemented on a larger scale in the KSA. Some of these barriers are cultural and related to customers' energy awareness and attitudes. Other barriers are institutional – for example, a lack of operational experience with implementing these types of programs. In this chapter, we describe each of the barriers that were identified by stakeholders. Then, in Chapter 10, we present a plan for enabling DSM in the KSA and overcoming these challenges.

The nine specific barriers to DSM implementation and adoption can be grouped into four basic categories. Economic barriers refer to the dynamics of the energy market and limitations that it may impose on DSM adoption. Regulatory barriers are generally policy-related challenges that are caused by a particular regulatory regime, market design, or market rule. Institutional barriers refer to limitations on internal capabilities within the KSA to design and execute DSM program deployment. Cultural barriers are related to customer attitudes toward DSM. The nine barriers are summarized in Table 9-1.

Table 9-1: Barriers to DSM Implementation and Adoption in the KSA

Category	Barrier
Economic	1. Low electricity prices 2. Lack of new cost-effective technologies
Regulatory	3. Low compliance with new standards 4. Financial disincentives for utility to implement DSM
Institutional	5. Lack of in-country operational expertise/experience 6. Lack of primary market data 7. Difficulty measuring and verifying impacts
Cultural	8. Low customer energy awareness (e.g., customer behavior) 9. Fear of customer backlash (e.g. "winners and losers")

9.1. ECONOMIC BARRIERS

<u>*Low electricity prices*</u>

Low electricity prices are a significant barrier to DSM adoption in the KSA. Because electric rates are so low, fewer DSM measures are cost effective compared to other regions of the world. In other words, it takes much longer for a customer in the KSA to break even on investments in energy efficient technologies since the incremental financial benefit of even large reductions in energy consumption can be fairly small. This was one of the most commonly cited barriers to

DSM implementation among stakeholders. Many asked, why should customers care about energy at these low rates?
While there is some truth to this concern, there are counterpoints that seem to have gone largely unnoticed by stakeholders. First, even at today's low energy prices, there are still many EE measures that are cost-effective with relatively short payback periods. These measures were identified in Chapter 7. Second, the price of energy has little to do with to cost-effectiveness of LM/DR measures, which instead focus on reducing investment in generating capacity and T&D capacity. These capacity costs are expected to contribute significantly to energy costs in the KSA unless they are addressed through demand-side programs. Still, it is likely that low energy prices have contributed to a general lack of energy awareness among customers, and that challenge is the subject of further discussion later in this chapter.

Lack of cost-effective new technologies

Some stakeholders put forward the argument that there is a lack of DSM technologies that are available for customers to adopt in the KSA. This could include, for example, high efficiency washers and dryers, or more efficient air-conditioning systems. These technologies are believed not to be available partly due to their longer payback period in the KSA as a result of low electric rates. The lack of available technologies also includes "automating technologies" such as programmable communicating thermostats. There is currently no demand for these technologies, because customers are not presented with a financial incentive to reduce consumption during high cost periods (e.g. a time-varying rate).

Once a market environment is created where it becomes profitable for equipment manufacturers, dealers and importers to sell new technologies in the Kingdom, they will begin to be sold to Saudi customers. Further, R&D funding to develop new DSM-related technologies in the KSA could help to create a market for these devices. This possibility is discussed further in Chapter 10.

9.2. REGULATORY BARRIERS

Low compliance with new standards

Efforts to develop standards for building efficiency have already been initiated to some extent by the Saudi Arabian Standards Organization (SASO). However, while this organization is clearly responsible for the development of standards, it is unclear who is responsible for enforcing those standards. A standard, no matter how detailed and well-developed, is not effective if it is not adhered to. For example, an organization needs to be made responsible for inspecting buildings and imposing penalties on builders who don't comply with the building code. Similar activities have to be carried out relative to equipment importers, dealers and manufacturers. This will become an increasingly important issue as new efficiency standards are introduced in the future as part of the DSM planning effort.

Organizational accountability for enforcing new energy efficiency standards is needed to address this barrier. The possible options for establishing such roles are discussed in Chapter 11.

Financial disincentives for utility to implement DSM

There may be a financial disincentive for SEC and Marafiq to implement DSM programs, particularly energy efficiency programs. These programs are designed to reduce consumption, and therefore sales. To the extent that the utilities' future sales are lower than expected due to the impact of DSM, then their revenues will be lower as a result. If electric rates are set to recover fixed costs, this could result in a net loss for the utilities.

In other regions, the disincentive to pursue DSM has been removed through a mechanism called "decoupling" which eliminates the link between sales and revenue. Some regions have also implemented mechanisms that allow the utility to earn an extra return on investments in DSM measures, to the extent that they produce target levels of benefits. These policy mechanisms, and how they could be implemented in the KSA, are the subject of further discussion in Chapter 10.

9.3. INSTITUTIONAL BARRIERS

Lack of in-country operational expertise/experience

A significant barrier to large-scale deployment of DSM programs in the KSA is a lack of internal experience in executing these types of programs. As discussed in Chapter 3, there are a few DSM initiatives already underway in the KSA. However, most of these programs are generally fairly moderate in scope and do not involve full-scale deployment to the mass market (i.e. residential and small commercial customers). As a result, DSM implementation expertise in the KSA is somewhat limited.

There are a number of ways that this lack of expertise can be addressed. Creating a market for experienced third parties to implement the programs is one approach. Another approach is to temporarily bring in external resources who can provide the skills and expertise necessary to train and educate staff at the organizations responsible for implementing the programs. A third option is to simply dedicate more internal resources from various Saudi organizations (such as SEEC) to these activities. All of these options are discussed further in Chapter 11.

Lack of primary market data

In developing potential estimates for each DSM measure, it became clear that there is a significant lack of market data available. This is data that would be very useful for developing a deeper understanding of the potential impacts of DSM programs and for developing targeted deployment plans in the future. For example, end-use appliance saturation data was very limited, and in the few instances where it was available (e.g., in recent NEEP reports) the numbers were often met with skepticism by various stakeholder groups. Another example is the absence of load research, such as hourly customer consumption profiles which would provide insights into customers' electricity usage behavior. Developing a robust database of such customer-specific data would dramatically enhance the value of future DSM studies and implementation efforts. Chapter 9 lays out a plan for collecting and developing this data.

Difficulty measuring and verifying impacts

There is concern among some stakeholders that it will be very difficult to measure and verify the impacts of the DSM programs. For example, how does one determine the extent to which load was curtailed during a LM/DR event? How does on estimate the "baseline" consumption level from which the load was reduced? And how can these impacts be integrated into supply-side planning? Currently, there are no established protocols for conducting such measurement and verification (M&V) activities in the KSA.

Accurate M&V is a critical component of three aspects of DSM program implementation: contract settlement, operational planning, and long-term resource planning. In other regions of the world, particularly the United States (California), this issue has been studied extensively and well-established M&V methods have been developed. Chapter 10 provides guidelines for developing M&V protocols.

9.4. Cultural Barriers

Low customer energy awareness

A key challenge will be overcoming customers' lack of understanding of the benefit of consuming less energy. The low level of energy awareness in the KSA is probably largely attributable to the Kingdom's artificially low electric rates (due to the domestic oil price subsidy). As a result of electricity being so cheap to customers, they currently have less interest in being energy efficient. There are other related issues that exacerbate this problem. For example, among larger residential customers, one stakeholder pointed out that the head of the household, who is paying the electric bill, often does not even see it. It is read and delivered to the utility by a housekeeper or someone else in a similar position.

This barrier can be addressed through a country-wide energy awareness campaign. Focus groups and customer interviews can help to shape such a campaign. The basic steps to developing a national awareness effort are discussed in Chapter 10.

Fear of customer backlash

As some DSM programs are rolled out – in particular, time-varying rates - they can create structural "winners" and "losers." Some customers will automatically experience bill savings by virtue of their low average consumption during high-priced peak hours. Other customers will experience bill increases if they do not take action and reduce their consumption during those high priced hours. Dealing with this dynamic, and particularly the reaction of those customers who are financially made worse off under the new pricing regime, is a concern to some stakeholders. There is also concern around customer reactions when their air-conditioners are cycled off as part of a DLC program.

In the near-term, customers could be given a bill guarantee, that they would be billed at the lower of the two rates (the current rate and the time-varying rate). Gradually, over a five-year period, this guarantee could be phased out. Another approach involves the provision of peak-time rebates. As discussed earlier in the report, customers who lower their usage during peak periods relative to a historically inferred baseline are rewarded with cash payments. If customers don't reduce their peak usage, they pay the bill they would have paid under current rates. If they lower their peak usage, they pay a lower bill. Since peak time rebates will only create winners, they are likely to be very popular with customers.[123] Another option that is less desirable for rates programs but an important characteristic of DLC programs is to make participation voluntary. These and other approaches to making DSM programs "customer friendly" are discussed in the program descriptions in Chapters 12 through 14.

[123] The key issue, of course, is the statistical procedure that is used to estimate their baseline use. Several techniques have been used successfully in other countries to develop baselines and they can be tried and tested with Saudi data.

10. ENABLING DSM IN SAUDI ARABIA

A major new DSM initiative is needed to overcome the barriers standing in the way of widespread program deployment. Simply fine-tuning the existing programs will not be enough. Rather, the initiative will require the bold development of a new DSM infrastructure that has the support and involvement of many key stakeholders across the country. Specifically, experience with DSM planning in other regions of the world suggests that there will be five key “pillars” to successful DSM enablement:

Pillar #1: Goal setting. Goals and targets are necessary for measuring the success of DSM programs and establishing accountability among the entities involved in implementation. They provide a clear and tangible objective for the DSM plan.

Pillar #2: Funding. The DSM programs proposed in this report are cost-effective, but require up-front investment and dedication of resources in order to realize their longer-term benefits. This means that a reliable and sufficient level of funding must be procured and dedicated to these programs before they can be offered to customers.

Pillar #3: Program Execution**.** Successfully executing the widespread deployment of DSM programs will require a multi-pronged approach. The elements of this approach include awareness campaigns, customer rebates and incentives, establishment of new codes and standards, modification to existing electric rates, and developing the market for new customer-side technologies.

Pillar #4: Implementation Incentives. Just as customers need an incentive to participate in DSM programs, there must also be an incentive for organizations to implement the programs. One approach is to use regulatory mechanisms to align the financial interests of the organizations with the objectives of the program.

Pillar #5: Measurement & Verification. Once the programs have been deployed, it is necessary to accurately track their performance. This is important from the perspective of settling customer participation payments, integrating the programs into future resource planning, and making mid-stream corrections to improve program performance.

These five pillars are the foundation of any successful DSM program offering. If any of the five pillars are not established, achievement of the program’s benefits will be put in jeopardy. The remainder of this chapter discusses each of the five pillars in further detail and provides preliminary recommendations for activities to support these initiatives. Some or all of these recommendations can be used as guidelines when developing a detailed implementation plan.

10.1. PILLAR #1: GOAL SETTING

To establish goals for a DSM program, one must first determine the overall objective of the program. Is the objective to reduce peak demand? Or is it simply to reduce total consumption, regardless of the timing? Are reductions in greenhouse gas emissions the primary concern? Or are reliability improvements and cost savings the bigger issue? Developing a single objective statement for the program can help to clarify these questions and add focus to the initiative.

Based on conversations with stakeholders and extensive working sessions with ECRA staff, it is clear that there is a primary objective of reducing peak demand in order to avoid capital investment in resources such as peaking plants (which are rarely utilized) and to improve system reliability. However, there is also an overarching desire to create greater energy awareness among customers in the KSA, and to make the overall consumption of electricity more efficient. To recognize these issues, we recommend the following simple objective statement to guide the DSM program:

Implementation Recommendation #1: Objective Statement

The objective of this program is to induce more efficient consumption of electricity in the KSA, with a specific focus on reductions in consumption during times of high demand. These impacts will be integrated into system planning processes to result in lower necessary grid investment.

With the objective statement established, the next step is to identify metrics that can be used to gauge whether that objective is being met. There is a wide range of potentially applicable metrics. These were recently summarized and evaluated in a report by JICA, and are reproduced with a few additions below:[124]

- Load factor
- Reduction in projected peak demand
- Reduction in projected overall energy consumption
- Consumption per unit of Gross Domestic Product (GDP)
- Consumption per capita
- Reduction in harmful environmental emissions
- Share of population with DSM technology (e.g. AMI deployment)

Each of these metrics has advantages and disadvantages. For example, some may be easier to measure while others may more closely relate to the specific objectives of the program. Simplicity has its advantages in the target-setting process. Keeping the number of targets low and the nature of the targets transparent will improve the likelihood that they are understood and met. Therefore, based on the stated objectives of this program, we recommend two relevant and simple metrics. These are (1) annual reductions system peak demand, and (2) annual reductions in total system energy consumption. These metrics can be accurately measured and verified using proven statistical techniques that are described later in this chapter. Together, they also can be translated into goals for improvement in the system load factor, which is an important measure of how well generation resources are being utilized.

The level and timing of the target metrics must also be developed. What are the annual levels of peak and energy reductions that are deemed to produce both feasible and meaningful benefits for the KSA? The analysis in Chapter 7 identified potential impact estimates for each possible DSM measure. Those can be aggregated to represent annual market potential estimates for each

[124] JICA, "The Master Plan Study for Energy Conservation in the Power Sector in the Kingdom of Saudi Arabia," July 2008.

program.[125] The result is an estimate of achievable DSM program impacts in the KSA. Based on those estimates, we recommend the following peak and energy impact targets:[126]

Implementation Recommendation #2: Targets

The DSM programs should aim to achieve the following measured and verified annual impacts in the specified timeframe:

	2016 (5 yrs from initiation)		2021 (10 yrs from initiation)	
	Peak (MW)	Energy (GWh)	Peak (MW)	Energy (GWh)
Direct load control	1,100	0	1,300	0
Interruptible tariffs	900	0	1,200	0
Curtailable load management	500	0	700	0
Efficient cooling	1,500	5,800	3,700	14,200
New construction efficiency	1,100	4,400	3,600	15,000
Total	**5,100**	**10,200**	**10,500**	**29,200**
Total as % of baseline	**8.5%**	**3.3%**	**14.0%**	**7.6%**

Based on today's annual load factor of 64 percent, these targets would translate into a three percent improvement in the load factor by 2016 and a four percent improvement by 2021. In 2021, this is equivalent to roughly a 14 percent reduction in total system peak demand (37 percent of all expected growth) and a 7.6 percent reduction in total system consumption (19 percent of expected growth).[127] At today's generation, transmission, and distribution costs, this could lead to SR 76 billion in gross financial benefits over the 10 year period (present value).[128]

An alternative possibility is to simply set the targets at the total peak and energy reduction levels, rather than assigning targets to each individual DSM program. This would provide the organization that is responsible for overall implementation with more flexibility in how it goes about achieving the target impacts.

It is necessary to remember that reductions in peak demand and energy consumption are means to an end, rather than ends in themselves. Ultimately, the reasons for pursuing these impacts are to reduce energy costs, improve system reliability, reduce emissions that are harmful to the environment, and create a more sustainable energy future for the KSA.

Importantly, these targets should be re-evaluated and refined as new data becomes available. The targets were developed using the best available Saudi market and load research data.

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[125] See Chapter 12 for a description of how these program-level estimates were developed using the measure-level impacts from Chapter 7.

[126] Note that these targets associated with a portfolio of programs that could be feasibly implemented in the short term. They do not include the potential for additional programs in the medium- and long-term.

[127] By comparison, the previously mentioned JICA report proposed a target of 50% reduction in peak demand growth between 2005 and 2015. This would translate into roughly 13 GW, or 23% of the system peak in 2015.

[128] See Chapter 5 for a description of the methodology behind this calculation. This estimate of avoided costs is based on the international market price of oil.

However, there are significant holes in that data, which had to be filled in using reasonable estimates from other regions. An effort to develop more a robust and comprehensive database of customer electricity data would significantly improve this exercise in the future. Recommendations for future data collection initiatives are provided in the sidebar at the end of this chapter.

10.2. PILLAR #2: FUNDING

None of the proposed DSM programs can be implemented without sufficient funding. A critical activity is to identify and secure a source of funding for each of the programs.

The first key question is who should provide the funding. A common approach used in other parts of the world is for the utility to make the up-front investment in the DSM programs, and then recover the cost through a surcharge on the electric bill (or through a temporary increase in rates). However, an alternative model may be more desirable in the KSA, where the requirement of a royal decree makes tariff modifications more difficult. In this case, a feasible model could be for a government agency such as MOWE to secure public funding for the program. In many ways, it makes sense for a program with societal benefits to be financed through public funds. This is particularly the case given that the DSM programs will reduce domestic oil consumption, therefore allowing more oil to be sold at higher prices on the international market, and benefiting the KSA economy. Further discussion of responsibilities related to funding is provided in Chapter 11.

A second important question is how much money will be needed for the programs to be implemented successfully. Annual budget estimates have been developed for each program. This includes, for example, equipment costs, program administration costs, marketing costs, incentive payments, and other program delivery-related costs. While the costs are described in more detail in Chapter 12, they are summarized here as suggested funding amounts to be secured for program implementation..[129] These are illustrative estimates only. As the KSA transitions into the implementation phase of its DSM effort and contracts are negotiated with suppliers, these estimates will need to be refined.

Implementation Recommendation #3: Dedicated DSM Funding

A government entity should secure public funding at the following levels for DSM program implementation:

	Annual Budget Examples (millions)										10-year Total
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	(Cumulative)
LM/DR	70	190	270	360	450	340	360	390	420	450	**3,300**
EE	700	1,600	2,900	4,300	5,300	4,300	4,600	3,300	3,500	3,700	**34,200**
Total	**770**	**1,790**	**3,170**	**4,660**	**5,750**	**4,640**	**4,960**	**3,690**	**3,920**	**4,150**	**37,500**

Note: Estimates are in today's currency (real terms) and do not reflect expectations of inflation.

[129] The bulk of the budget forecast would be dedicated to cash rebates and customer incentives for EE programs. More detail is provided in Chapter 13.

Finally, a regulatory approval process will need to be established for the implementation organizations to receive funding. This process would require that the organizations demonstrate that their costs are reasonable and that they have a thorough and comprehensive plan for delivering benefits that are greater than the costs. In most other regions, this involves the submission of a plan or business case to the regulatory authority, which reviews the application through an open public process. The regulator then approves the application, denies it, or provides conditions upon which it will be approved after modification.

Implementation Recommendation #4: Funding Approval

Establish a set of criteria which implementing entities must meet in order to receive funding. The criteria should be consistent with the objective of proving that costs are reasonable and that benefits are likely to outweigh the costs.

10.3. PILLAR #3: PROGRAM EXECUTION

Program execution is perhaps the most important of the five pillars of implementation. It encompasses all of the major activities that are needed to encourage program adoption in the KSA. What means will be used to encourage customers to become more energy efficient? What type of market transformation or tariff changes will be needed to enable meaningful participation? Based on the observed best practices of other countries around the globe, there are five complementary activities that could be used to encourage program adoption: Awareness campaigns, cash rebates, codes and standards, modifications to electric rates, and new technology development.

These five keys to program adoption will have varying degrees of feasibility in the KSA. Based on the *Brattle* team's stakeholder interviews, it seems that awareness campaigns and rebate programs are likely to encounter the most acceptance and support. These approaches tend to only produce "winners" who benefit from the programs. Codes & standards and new technology development (e.g., R&D funding) are also likely to have support among the key stakeholders. However, they include some additional implementation challenges that make them slightly more difficult to execute, such as enforcing the standards and securing R&D funding. Finally, modifying electric rates to reflect the true market price of energy is a proven way to encourage more efficient energy use, but has greater political challenges than the other activities. The five keys to DSM program adoption are summarized in Table 10-1.

Table 10-1: The Five Keys to DSM Program Adoption

Key Element	Activities	Immediate Feasibility
1. Awareness	National campaigns that promote greater customer awareness of electricity consumption behavior and its impact on society	High
2. Cash rebates	DSM programs that provide rebates / payments to customers for load curtailment or purchases of energy efficient technology / materials	High
3. Codes & standards	Regulations that establish minimum efficiency levels or otherwise create requirements related to adoption of efficient technologies	Moderate
4. New technologies	Developing the market for energy efficient technologies through research and development (R&D) funding	Moderate
5. Electric rates	Modifying the current tariff to eliminate subsidies and reflect the true price of energy, by time-of-day and based on market prices	Low

10.3.1. Awareness

A national energy awareness campaign is an important step toward addressing the low level of awareness among customers in the KSA today. As described in Chapter 9, a number of factors, most notably the low energy price, have limited customer awareness and understanding of the societal implications of high energy use. A media-based effort to educate customers about the potential benefits of using less energy, and the options that are available for reducing their usage, would be valuable to the KSA's DSM initiative.

Energy awareness campaigns have demonstrated success in other regions. A good example is California's "Flex Your Power" program that was initiated during the energy crisis of 2000 and 2001.[130] The program provides no financial payment to customers; it is simply a statewide announcement that power cuts are needed in order to avoid rolling blackouts across the state. Announcements are made through common media channels such as radio, TV, and he internet, and customers are provided with tips about easy measures that can be taken to reduce consumption (such as turning off unnecessary lights or postponing the use of major appliances until off-peak times). During California's energy crisis, the program was attributed with achieving significant load reductions.[131] Due to its success, the program continues to be utilized in the state today. This is an option that is also being considered by the Japanese in response to their recent national crisis, which has shut down several nuclear reactors and could lead to up to 10 GW of supply shortage in the coming months.[132]

130 For details of the program, see http://www.fypower.org/.

131 While no official estimates of load reduction exist, conversations with industry experts have suggested that these types of programs can produce a five percent reduction in peak demand of homes and small businesses.

132 Based on email correspondence with TEPCO staff.

To be impactful, the "message" of the awareness campaign will need to resonate specifically with the people of Saudi Arabia. This will require primary market research. Since consumer awareness is likely to vary by segment, it is first advisable to gain insights through consumer focus groups in each of the operating areas involving different customer classes. It would be best to conduct two waves of focus groups. In the first wave, an initial understanding of current awareness levels can be developed. These should be a followed by a second wave of focus groups in which different ways of communicating the importance of demand response can be tested and refined. As the message takes shape, it could be further tested through surveys that reach out to larger numbers of customers.

Implementation Recommendation #5: Energy Awareness Campaign

Develop and implement a nationwide energy awareness campaign with the following qualities:

- Awareness message tailored to Saudi culture using primary market research
- Message identifies need for energy reduction and ways to reduce consumption
- Campaign utilizes all feasible media channels
- Measurement & verification of impacts to assess program effectiveness

10.3.2. Cash Rebates

A common feature of many of the DSM programs that have been recommended for short-term deployment is that they would provide cash rebates to encourage participation. Rebates are an effective mechanism for encouraging participation, because a long history of success in DSM programs demonstrates that customers respond to financial incentives. In establishing program rebates, there are two major decisions to be made: (1) how to structure the rebate and (2) the rebate amount.

Rebate payments can be structured in many different ways, depending on the nature of the DSM program. For example, participants in a curtailable load management program typically receive a payment per kilowatt-hour of curtailed consumption during LM/DR events. Alternatively, participants in a DLC program often receive a monthly payment simply for being enrolled in the program, regardless of how many times it is used. Participants in an energy efficiency lighting program might receive a rebate for each efficient light bulb that they purchase. Rebate payment structures are very program-specific and are in fact the only major distinguishing characteristic of certain LM/DR programs.

The payment amounts in these programs would vary as well. Rebate payments are often higher for programs that provide more reliable consumption reductions or that provide more dispatch flexibility (e.g. no limit on the number of allowed LM/DR events). These qualities justify a higher payment because they are more valuable to the organization that is dispatching and utilizing the program. They also tend to be qualities that are less attractive to customers, who would need a higher incentive payment to participate. Incentives are generally set at levels deemed necessary to induce sufficient customer participation and response without compensating customers at such a high rate that it negates the cost-effectiveness of the program.[133]

Illustrative rebate payments for each short-term DSM program are provided in Chapter 12 of this report. These are intended to provide a starting point for visualizing each program, but are subject to further market research as the deployment plans are further developed. They are based on best practices incentive structures from other DSM projects around the globe, and developed to link the programs to the economic conditions of the Saudi Arabian electricity market.

Implementation Recommendation #6: Rebate Payments

Deploy a portfolio of rebate-based DSM programs. In the short-term, this would include direct load control and curtailable load management. Aspects of cooling efficiency and new home efficiency programs may also include rebate incentives.

In addition to the programs that are recommended for short-term deployment in this report, there is another unique rebate program that could be considered for addressing very short-term capacity shortage issues the KSA. This is an energy quota system, similar to the one utilized by Brazil (as described in Chapter 2). The program would specify a target level of energy reduction and either compensate customers for reducing their consumption by that amount, or penalize them for consuming above that amount. Due to inherent inaccuracies in the ability to very accurately measure the customer-level reductions, it is recommended that a payment approach be used, rather than a penalty approach to avoid customer backlash.

Energy quota programs can be extremely effective. The Brazilian power rationing program achieved a 20 percent reduction in monthly consumption during a nine month period in 2001 and 2002. California implemented a similar program (called "Energy 20/20") which is credited with producing 2,600 MW of peak demand savings and a participation rate of 34 percent of the state's residential customers.[134] However, these programs can also be quite costly. In Brazil, due to the high achievement of participants, the country paid out over $200 million in rebates.

Ultimately, energy quota programs are effective for quickly achieving significant impacts, but those impacts often come with a hefty price tag. Therefore, we recommend that they be considered, but only for use in the short-term and in emergency situations.

Implementation Recommendation #7: Energy Quota Program

To address very short-term emergency capacity shortage situations, the KSA should consider offering an energy quota program that provides payments to customers for achieving target reductions in monthly energy usage. However, when considering an energy quota program it is important to weigh the benefits against the potentially hefty rebate costs.

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133 Rebate levels would need to be determined through market research in the KSA.

134 Customers were given a 20% rebate on their electricity bill if they were able to reduce consumption by 20% relative to the same month from the previous year. For more information see http://www.energy.ca.gov/releases/2002_releases/2002-05-23_governor_20-20.html

10.3.3. Codes and Standards

As an alternative to rebate programs, energy efficiency can be induced through codes and standards.

California is a classic example of the significant impact that codes and standards can have on energy use. Historically, per-capita electricity consumption in the United States has grown at an average rate of seven percent per year. However, in California, it has remained flat since the 1970s. Figure 10-1 illustrates this point.

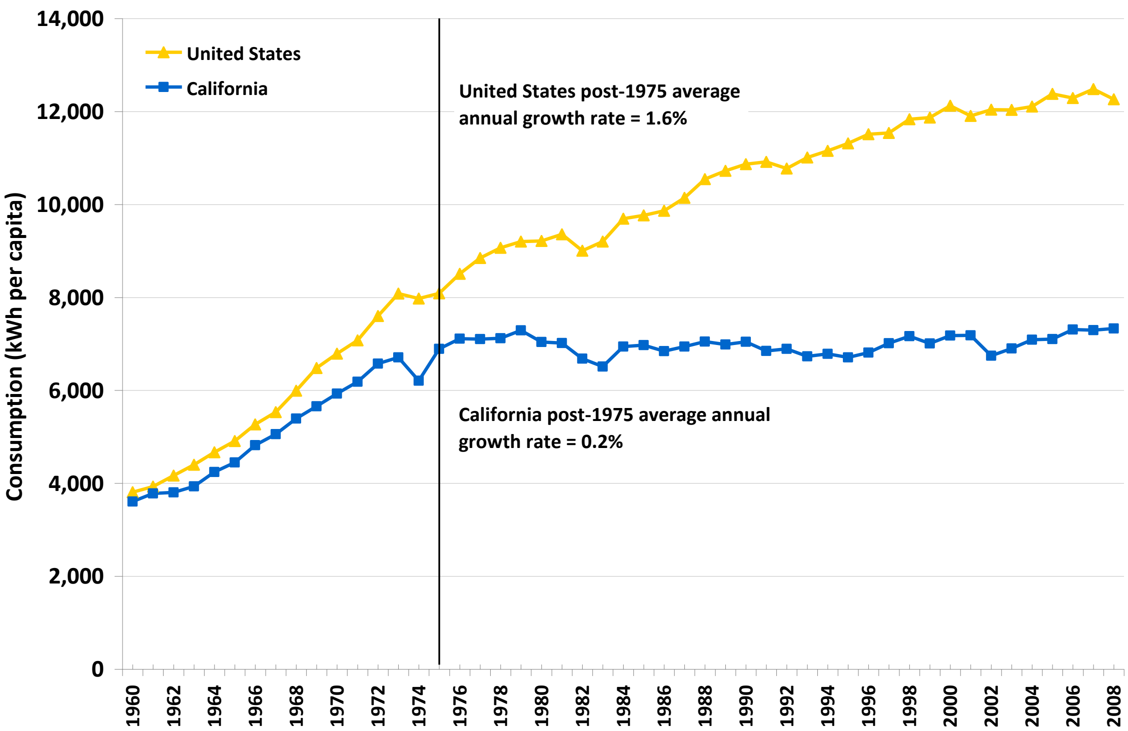

Figure 10-1: California versus United States Electricity Consumption per Capita

California's energy efficiency standards are major factors that have contributed to this trend. Of the energy savings that are attributable to energy efficiency initiatives, roughly half are due to codes and standards, and the other half are due to utility rebate programs. Thus, the two approaches carry roughly equal weight in the state's portfolio of energy efficiency initiatives. Figure 10-2 illustrates the contribution of both approaches to historical energy savings in California.

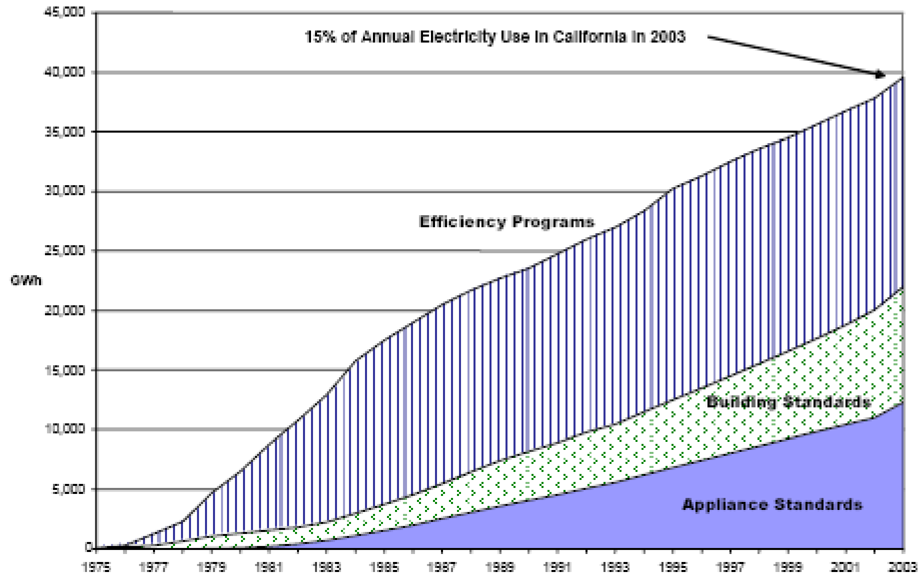

Figure 10-2: Cumulative Energy Savings of California Energy Efficiency Standards and Programs[135]

Codes and standards are primarily used to promote energy efficiency. However, they could also be applied to LM/DR. For example, one could envision a load management standard that requires that smart thermostats be installed in all new homes. An alternative standard could be to require that all large commercial customers install Auto-DR systems. In fact, the California Energy Commission (CEC) explored these options as recently as 2007 in an effort to revisit load management standards that it had developed in the 1970s. [136] However, changes in leadership at the CEC and some political challenges have suspended that effort.

To initiate the development of DSM standards in the KSA would likely require the joint involvement of a number of entities, with SASO in the lead (specific roles are discussed further in Chapter 11). The process could be initiated with public workshops on DSM standards, to demonstrate their potential in the KSA. This has already been accomplished to some extent through the recent *Brattle* workshops and meetings with stakeholders in late 2010 and early 2011. Then, a second workshop could be held to present "strawman" standards on which the stakeholders could provide feedback and comment. Through this process, it would also be necessary to identify the organization that would take the lead in enforcing the standards. That is critical to the success of the initiative, as there currently is not an organization that is responsible for enforcing the new Saudi Arabian building code and it is believed to be relatively ineffective as a result. Proposed standards related to cooling and new building efficiency are discussed further in Chapter 12.[137]

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[135] Source: CEC Staff Report, "Options for Energy Efficiency in Existing Buildings," December 2005.

[136] See Ahmad Faruqui and Ryan Hledik, "California's Next Generation of Load Management Standards," prepared for the California Energy Commission, May 2007.

[137] The specific efficiency levels that would be required by the codes and standards would need to be determined during the early stages of program implementation.

Implementation Recommendation #8: Codes & Standards

Develop standards that specify a minimum level of efficiency for cooling and new buildings. Conduct a series of public workshops or hearings on these standards, with the objectives of (1) demonstrating the value of the standards in the KSA, (2) incorporating stakeholder feedback, and most importantly, (3) identifying the organization that will be accountable for enforcing the standards.

10.3.4. New Technologies

Promoting the development of a market for new DSM technologies could significantly improve the impact of DSM programs. For example, studies have found that being equipped with an enabling technology (such as a smart thermostat) can nearly double a customer's price responsiveness (i.e. load reduction). Energy efficient technologies, of course, inherently provide energy savings, but have low adoption rates in the KSA due to the artificially low energy prices.

One approach to developing the market for DSM technologies in the KSA is to dedicate research and development (R&D) funding to the technologies. A model that is being used in some areas, including the Gulf region, is to develop "smart grid cities." These initiatives are typically collaborations between the utility, smart grid technology manufacturers, and other interested stakeholders. They are intended to demonstrate how a fully integrated smart grid can be practically implemented. In Abu Dhabi, Masdar City was established in 2006 as a way to demonstrate the future of sustainable cities. It currently includes several highly efficient buildings that have reduced energy and water use by roughly 50 percent through a combination of efficient and renewable technologies.[138] Future developments will include initiatives related to more efficiency in transportation and development of clean sources of power.

In the KSA, where public funds are used to develop entire cities from the bottom up (e.g., the Jubail and Yanbu industrial cities), one could envision a city that is dedicated to demonstrating energy efficiency. This could apply broadly to overall energy use (not just electric efficiency). While the city would be an opportunity to prove the benefits and feasibility of new technologies, it would also be a signal to outside investors and green technology manufacturers that the KSA is moving toward a more efficient energy future. One such effort has already been initiated by MOWE, to demonstrate the potential for energy efficiency in a government building.

[138] For more information see: http://www.masdar.ae/en/MediaArticle/NewsDescription.aspx?News_ID=150&News_Type=PR&MenuID=0&CatID=64

Implementation Recommendation #9: Energy Efficiency City

To encourage the maturation of the DSM technology market in the KSA, consider funding the development of a city that can be used to demonstrate the benefits of energy efficiency. Develop the city through partnerships with a wide range of interested stakeholders, including smart grid technology manufacturers.

It is also likely to be the case that the market for DSM technologies will develop naturally as the other aspects of the implementation plan are deployed. For example, new codes and standards related to appliance efficiency will create immediate demand for more efficient technology. Similarly, programs that provide rebates for load curtailment will improve the economics of enabling technologies like smart thermostats.

10.3.5. Electric Rates

The most significant barrier to energy efficiency adoption in Saudi Arabia is the artificially low electric rate. A way to induce greater energy awareness and improve economic efficiency is to adjust the rate to reflect the international market price of energy. Countless studies have shown that customers reduce electricity consumption when the price increases. Typical estimates from other regions suggest that, in the short term, a doubling of the price of electricity could cause consumption to drop by 10 to 30 percent.[139] The long-term impacts could be even higher. Therefore, given that current electricity prices in the KSA are roughly a sixth of the market price, even a partial adjustment to the rates could have significant efficiency and conservation benefits.

Once smart meters are deployed across the country, it will also be possible to structure rates that vary by time of day (e.g., the TOU rate currently offered to large commercial and industrial customers). As discussed throughout this report, these rate designs encourage more economically efficient electricity consumption by aligning the price the customer sees with system costs.

There are challenges to modifying the tariff, particularly for the residential segment. Therefore, this is a better medium- to long-term solution than something that is feasible in the short term. However, in the short term interruptible tariffs could be provided as a voluntary option for large commercial, industrial, and government customers that are already equipped with the necessary metering capability. As described elsewhere in the report, interruptible tariffs provide a financial incentive to reduce consumption during LM/DR events, typically by offering a discounted electricity rate as an incentive to participate.

[139] This corresponds to a short run price elasticity of -0.1 to -0.3. See the RAND survey "Regional Differences in the Price-Elasticity of Demand for Energy," 2005.

Implementation Recommendation #10: Cost-based Electric Rates

Modify the existing tariff for all customer segments to reflect the true cost of electricity. Modifications should reflect the international market price of energy and the time-varying nature of electricity costs. Rates should be piloted before being fully deployed. For short-term deployment, interruptible tariffs should be offered on a voluntary basis to encourage peak load reductions.

10.4. PILLAR #4: REGULATORY INCENTIVES

Without certain regulatory mechanisms in place, utilities generally have a financial disincentive to pursue DSM. The reasons for this are threefold. First, implementing a DSM program costs the utility money. A source of funding is needed, either through public funds or a rate increase. Second, even with the costs of the programs covered, the objective of DSM programs is to reduce consumption, and therefore sales, which results in lower revenue for the utility. Finally, even if the lost revenue were recovered by the utility, DSM programs are only made comparable to supply side resources – utilities do not have a reason to prefer the DSM programs unless they are able to capture a share of the resulting cost savings as financial benefits (rather than passing all savings through to the customer).

A three step approach can be used to align the incentives of the DSM programs with those of the utility:

1. *Direct cost recovery:* This is the most common form of regulatory incentive. It allows utilities to recover the DSM program implementation costs in a timely manner. It is also the weakest of the three mechanisms for promoting DSM. As suggested earlier in this chapter, in the KSA, funding for direct cost recovery will likely need to come from the government since there are challenges to modifying the tariff.

2. *Decoupling:* With decoupling, the link between sales and revenue is removed. Utilities are allowed to earn a reasonable level of revenue based on cost and sales forecasts that are reviewed and accepted by the regulator. With decoupling, if sales end up being lower than forecast due to significant DSM impacts, the utility still earns the full revenue amount and is not made worse off as a result. In the KSA, this would require regulatory oversight and approval of the sales forecasts which, when multiplied into the existing electricity rates, would produce the approved utility revenue amounts. In some regions, this requirement makes decoupling unattractive. Either the utility does not like to lose the potential upside of a year with high growth in sales, or the regulator or other interested stakeholders do not like the idea of relying on sales forecasts to compensate the utility. Whether this is attractive in the KSA will depend on the opinions of ECRA, the utilities, and other stakeholders.

3. *Shareholder incentives:* This includes all models that are designed to provide utilities with a financial incentive to pursue DSM above and beyond earning their expected

revenues. A recent example is Duke Energy's Save-a-Watt model, which gives the utility a financial bonus that is equal to a portion of the avoided supply-side costs that are achieved through DSM programs. This model essentially shares the benefit of the DSM program between the utility's shareholders and its customers. It also is a way to sweeten the deal for investors who may otherwise be averse to the perceived risk associated with new customer-side programs. California's Shared Savings model and Nevada's enhanced ROE models are similar examples. These models all include target impact levels. The utilities receive the incentive payment if the targets are met. If they are not met, a financial penalty is incurred.

In the KSA, the first two mechanisms (direct cost recovery and decoupling) both have potential. It is not likely that the utilities will pursue significant levels of DSM adoption if it is directly opposed to their financial interest. Whether a shareholder incentives model should be implemented is more questionable. While SEC is technically a publicly owned company, the government still essentially has a large stake in the company's finances. Therefore, an additional incentive for shareholders may not be necessary.

Implementation Recommendation #11: Regulatory Incentives

Establish a mechanism for publicly financing the implementation costs of utility DSM programs. Also consider establishing a decoupling mechanism, which removes the link between the utilities' sales and revenue to eliminate disincentives to pursue DSM. Explore the attractiveness of a shareholder incentives mechanism with stakeholders.

10.5. PILLAR #5: MEASUREMENT AND VERIFICATION

To accurately assess the benefits of DSM, it is necessary to have standardized practices for quantifying demand reductions. Specifically, M&V plays an important role in three areas. First, it is needed to settle DSM contracts. In order to compensate a participant in a curtailable load management program, for example, one must use M&V methods to estimate the amount of load that the participant curtailed. Second, M&V is needed to effectively integrate DSM impacts into long-term resource planning. Most benefits of DSM (particularly LM/DR) can only be realized once they are reflected in resource planning. For this to happen, the organizations responsible for the planning (e.g., SEC and Marafiq) must have confidence in the likely future impacts of the programs. Third, M&V is important to operational planning, to enable system operators to predict short-term (day ahead) impacts of the DSM resources.

M&V protocols will need to be established for the KSA. The elements of M&V protocols from other regions could be used to form the basis for a similar approach in the KSA.[140] Specifically, M&V protocols in the KSA should require that some or all of the following elements be provided by the organizations responsible for conducting the M&V analysis:

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[140] See, for example, NERC, "Data Collection for Demand-Side Management for Quantifying its Influence on Reliability: Results and Recommendations," December 2007. Also see CPUC D.08-04-050 issued on April 28, 2008 with Attachment A.

- *Schedule and budget:* A timeline for conducting all necessary aspects of the evaluation and an estimate of the budget necessary to complete it.

- *Statistical measures:* A description of the statistical measures that will be used to estimate the program impacts. Examples of possible approaches are described in Appendix I.

- *Granularity in impact estimates:* A description of the level of granularity to be reported; typically includes hourly detail on LM/DR event days and estimates of changes in overall energy consumption by season and year for each measure

- *Uncertainty in impact estimates:* A range of impact estimates to represent level of precision of model parameters and uncertainty in key variables such as weather
- *Reporting format:* A consistent reporting format should be used for each DSM measure to allow for comparisons across measures.

- *Forecasts:* In addition to providing ex-post estimates of program impacts, the plan should also identify an approach to developing forecasts of DSM impacts for the purposes of integration into system planning.

As DSM programs are rolled out and the impacts of the programs are measured and verified according to these protocols, they results will need to be published in an annual or bi-annual report that documents the progress of the programs against key performance indicators (the peak and energy reduction targets). Additionally, as the programs are implemented there surely will be unexpected challenges that will need to be dealt with. The program reports would also serve as the appropriate venue for documenting lessons learned while implementing the programs.

Implementation Recommendation #12: Measurement & Verification Protocols

The KSA should establish M&V protocols for evaluating the impacts of DSM programs and incorporating them into system planning. These protocols will represent a standardized list of reporting requirements to be followed by the organizations conducting the M&V analysis. The product of the M&V analysis should be annual reports that document the progress of the programs relative to key performance indicators (peak and energy reductions) and document lessons learned during program implementation. Additionally, the KSA should establish a load research program to collect data that will better inform future DSM planning efforts.

The approach to evaluating the impacts of DSM programs can be very simple or very complex. For example, it can be as simple as comparing one month's consumption to consumption during the same month of the previous year. Or can involve sophisticated statistical analysis which controls for the affects of weather, economy, and other factors that may influence electricity consumption behavior. Generally, while the more sophisticated analyses require a higher level of training and expertise to be implemented effectively, they also are necessary to accurately isolate the impact of the DSM program that is being evaluated. Technical guidelines for selecting an impact evaluation method are provided in Appendix I.

SIDEBAR: FUTURE DATA COLLECTION RECOMMENDATIONS

Throughout the course of this project, we identified several areas in which a more robust data collection effort is needed. Access to this data would help to refine the DSM potential estimates that are provided throughout this report, thus enhancing stakeholder confidence in the conclusions and improving the estimation of reasonable DSM impact targets. The specific areas for further data collection are described below.

Hourly customer segment load profiles: Individual hourly load observations should be collected for a representative sample of utility customers by segment. The samples should be representative of the entire population across a range of sociodemographic variables and should geographically encompass all major regions of the KSA. This information will be helpful for establishing a baseline (i.e. control group) against which the impacts of DSM programs can be evaluated. It will also be helpful for developing basic segment-level statistics such as each segment's coincident contribution to the system peak.

Archived historical hourly system load: Historical hourly system load data was only available for 2007 and later years. To accurately assess trends in the system load factor and the potential effectiveness of LM/DR programs in the future, a longer history of system load data is needed. It should be located in the archived utility files. Existing data should be saved and stored for future use.

Refined customer segmentation: Most data was only available for basic customer segments: residential, commercial, industrial, government, agricultural, and other. For a more refined assessment, these segments could be further divided into sub-segments to reflect more specific customer types (e.g., mosques, schools) and sizes (e.g. small, medium, and large industrial customers based on demand thresholds).

End-use appliance and equipment saturations: Limited data was available on the share of customers with various electric appliances and equipment types. NEEP reported some of this data, but its accuracy was disputed by stakeholders. A detailed appliance saturation survey should be conducted across all customer segments throughout the KSA.

Impact evaluations of existing programs: Limited information is available on the impacts of existing DSM programs. For example, estimates of peak reduction from the TOU rate were provided in the aggregate, with little detail on how they were developed and no estimates of customer price elasticity. This is information that would be very useful for extrapolating that experience to the larger population of customers.

Studies of historical customer price elasticity: It would be useful to conduct a study to measure how customer consumption levels have changed in response to historical changes in the electric tariff.

Improved load forecasts: Load forecasts could be enhanced to account for the impact of the economy and other variables that have an impact on electricity consumption (in addition to the basic factors such as changes in the sectoral mix).

11. ORGANIZATIONAL ROLES AND RESPONSIBILITIESRESOURCING

DSM has not achieved its potential in the KSA for a variety of reasons that have been described in the preceding chapters. The execution of DSM programs has been limited by lack of funding and by ambiguous assignment of responsibilities. It is difficult to know what has been done, by whom it has been done, and what results it has achieved. No comprehensive annual report is prepared summarizing goals and achievements and there is no documentation of lessons learned to date which may guide future programmatic development.

Several of the key barriers to DSM implementation and adoption in the KSA (previously described in Chapter 9) are directly the result of the limitations of current DSM organizational accountability and experience within Saudi Arabia. From our experience with similar DSM programs in other countries around the world, the organizational roles, responsibilities and experience form the foundation for the DSM enabling "pillars" described in Chapter 10. Without a solid foundation of specific DSM organizational accountabilities within the KSA, any DSM implementation effort will produce sub-optimum results, or even complete failure.

In order to ensure a successful and sustainable DSM implementation strategy for Saudi Arabia, the current organizational limitations must be addressed, and organizational roles and responsibilities of the various institutions involved in DSM implementation must be clearly defined. The following key questions need to be addressed for any new implementation organizational structure in the KSA:

- How can the current organizational barriers and concerns be overcome?
- What is the optimum organizational structure to maximize benefits in the Kingdom?
- How can we improve our current level of skill and experience as it relates to DSM implementation?
- What is the role of third-parties in supporting implementation?

The purpose of this chapter is to provide specific recommendations for new organizational accountabilities in order to ensure the creation of a DSM implementation foundation within the KSA. In addition, this chapter will outline several capability building options for addressing the current lack of skills and experience with implementing the DSM programs recommended in this report. Each DSM capability building option has its pros and cons for implementation in the KSA. Therefore, each option should be carefully considered by all stakeholders prior to implementing our DSM program recommendations.

11.1 CURRENT ORGANIZATIONAL ACCOUNTABILITIES

As the two electric utilities in the KSA, SEC and Marafiq are currently the key drivers of actual DSM implementation from an organizational responsibility perspective. Other key institutions, such as MOWE, ECRA, SEEC, and SASO, currently provide overall program approval, enabling regulations, tariff setting arrangements, direction, funding, and support, including DSM implementation "monitoring" roles. Figure 11-1 describes the current DSM organizational structure and current implementation responsibilities within the KSA.

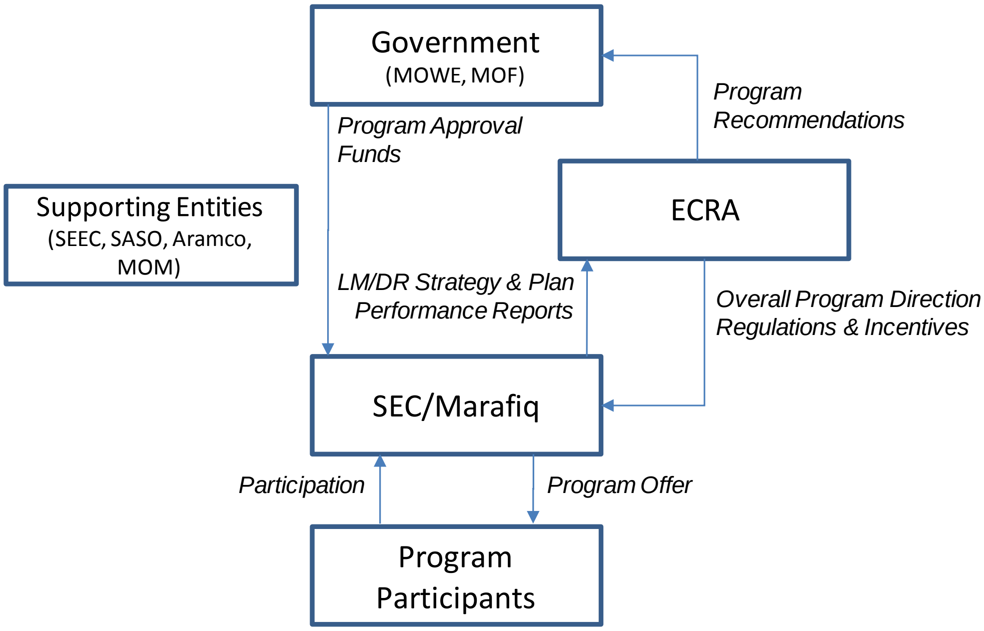

Figure 11-1: Current DSM Organizational Structure & Implementation Responsibilities

However, the current accountabilities are not well defined and organizational responsibilities are somewhat blurred between the various institutions. This has contributed to the lack of historic DSM progress and impact within the KSA to date. It is also unclear what resources have been spent on DSM implementation within the KSA or the level of funding allocated to DSM activities by each organization. What is clear is that the organizations have not been successful in clearly tracking results, chronicling past programs, and identifying lessons learned.

Redefining the current organizational structure and responsibilities, and identifying possible alternative structures, will help to increase the likelihood of successful implementation of future DSM programs in the KSA.

11.2 Revised Organizational Accountabilities

As previously mentioned, one of the key challenges to implementation will be strengthening the organizational roles, responsibilities, and experience within the KSA. This will provide the foundation for the DSM implementation enabling "pillars" described in Chapter 10.

While many of the proposed organizational accountabilities may not necessarily be new to the institution, it is imperative that each organization is committed to implementing DSM. Organizational objectives and responsibilities for implementation will also need to be established within each institution. Finally, the various institutions within the KSA must be aligned and accountabilities agreed to prior to implementation of any DSM program.

Without clear expectations of each institution's new accountabilities, any DSM program implementation within the KSA will continue to be limited by the regulatory and institutional barriers described in Chapter 9.

The key proposed changes to the organizational accountabilities are highlighted as follows:

- MOWE – Funds all DSM activities
- ECRA – Oversee implementation for DSM and provide independent measurement & verification
- SEC/Marafiq – Build/ Invest in LM/DR capabilities and expertise
- SASO – Enforce EE standards and codes
- SEEC – Administer all EE program development and implementation
- Project Management Office (PMO) – Drive actual day-to-day implementation efforts within the KSA; a new, non-permanent entity under one of the organizations above

MOWE

MOWE, or another other appropriate government entity such as the Ministry of Finance (MOF), will need to provide the necessary funding to implement DSM within the Kingdom. While the benefits of such programs are potentially quite large, in many cases they will be societal benefits and may not always be in the best interest of SEC or Marafiq. Hence, it would be unfair for SEC or Marafiq to bear all the costs of implementing DSM.

In other countries, regulators incentivize the utilities they regulate to engage in DSM by letting them raise rates to (a) recover the amount they spend on DSM (b) recover revenues that are lost when sales go down and fixed costs still have to be covered and (c) provide a bonus to shareholders for engaging in an activity that seems counter intuitive to their core mission of supplying energy to meet customer needs. Similar to many other countries around the world, MOWE and MOF will need to provide the necessary funds for implementation to implement programs that will benefit everyone in the KSA.

ECRA

As the electric regulatory authority within the KSA, ECRA is best positioned to provide overall administration oversight of DSM program implementation in Saudi Arabia. In addition, ECRA's current oversight responsibility for utility operations, economics, and tariffs makes the authority best positioned to provide unbiased, independent verification and measurement of DSM program activities within the KSA.

SEC / Marafiq

SEC and Marafiq will need to invest in building their internal LM/DR capabilities and expertise. Without addressing the critical skills and capabilities gap, the limited achieved impact from LM/DR programs will continue. As key implementers of LM/DR programs within the KSA, SEC and Marafiq must be required to invest in building the LM/DR skills and expertise and/or be required to bring in third-party consulting help to implement such programs. Without such capability building requirements, LM/DR implementation will be significantly limited.

SASO

SASO's current role of developing Saudi Arabian building codes and appliance standards will need to expand to include enforcement of such codes and standards. As previously discussed in Chapter 9, a standard, no matter how detailed and well-developed, is not effective if it is not adhered to. SASO is best positioned to be made responsible for inspecting residential and commercial buildings and imposing penalties on builders who don't comply with the building code and enforcing equipment importers, dealers and manufacturers to adhere to new application standards and requirements.

SEEC

SEEC will need to administer all EE programs within the KSA and provide oversight responsibility for these activities. As a newly formed organization, its ability to currently oversee all EE program implementation may be limited today. However, it is expected that SEEC will be the primary authority in EE program development, implementation and monitoring within the KSA.

PMO

A PMO will need to be created that is focused on all day-to-day, tactical activities related to DSM implementation within the KSA. It is envisioned that the PMO would be a new, temporary group comprised of DSM experts to help launch the efforts under the program. The PMO would bring the critical skills and capabilities, initially through external third-parties and consultants, to the DSM implementation efforts which are currently in limited supply within the KSA. This is described further in Section 11.3.

Table 11-1 summarizes the revised institutional accountabilities for DSM in Saudi Arabia.

Table 11-1: Revised Institutional Accountabilities for DSM in Saudi Arabia

Entity	Revised DSM Accountabilities
Ministry of Water and Electricity (MOWE)	• Lead overall DSM, energy conservation and efficiency strategies and policies • Prepare, endorse and follow-up on the execution of programs • Develop and implement a public awareness plan • Fund DSM activities within the KSA
Electricity and Co-generation Regulatory Authority (ECRA)	• Oversee DSM implementation within the KSA • Modify the regulatory framework to encourage the utilities to pursue DSM and provide DSM supportive regulatory frameworks and tariffs/ incentives for programs • Adopt a long term plan that include increasing DSM activities • Provide independent measurement and verification of DSM activities
Saudi Electricity Company (SEC) / Marafiq	• Implement LM/DR programs and measures within the KSA • Support research in EE technology • Collaborate in implementing efficiency awareness • Build and invest in DSM capabilities within the organization
Saudi Arabian Standards Organization (SASO)	• Develop new household appliance/ EE standards and labeling program • Develop EE building codes and standards for residential and commercial buildings • Promote standards awareness • Enforce new EE codes and standards
Saudi Energy Efficiency Center (SEEC)	• Administer (develop, monitor and coordinate) all EE programs • Promote EE activities within the KSA
Project Management Office (PMO)	• Drive day-to-day implementation efforts through a new, non-permanent group • Bring needed DSM skills and expertise to the program efforts and build upon them within KSA

11.3 Capability Building Options

Clearly defining the organizational roles and accountabilities within the KSA is a critical first step towards successful DSM implementation. However, the limited amount of DSM skills and expertise within the KSA must also be addressed in order to ensure successful DSM program implementation. This lack of DSM expertise has been identified as a key impediment for implementation within the KSA.

There are a number of ways that this capability gap can be addressed. One option is to simply dedicate more internal resources from various Saudi organizations (such as SEEC) to these activities. Another approach is to temporarily bring in external resources that can provide the skills and expertise necessary to train and educate staff at the organizations responsible for implementing the programs. A third approach is to create a sustainable market for experienced third parties to implement the programs within the KSA.

Capability Building Option 1 – Add Internal Resources (No Change)

In this option, DSM program implementation responsibilities fundamentally remain unchanged. In essence, Figure 11-1 remains in effect and new internal resources from within the KSA are reassigned to ensure any DSM implementation requirements are met. Specifically, any DSM skills and expertise currently residing within other KSA institutions, such as MOWE, SEEC, KACST, etc., would be assigned to SEC or Marafiq to help ensure successful implementation.

This option still represents "status quo" in terms of DSM implementation. However, the fundamental implementation issue remains, which is that there is a capability gap in the number and quality of DSM implementation resources within the Kingdom. It is unclear how many DSM resources trained in implementation and program management even currently exist within the KSA. Redeploying a limited number of skilled resources within the KSA may not be enough to ensure successful implementation of all the LM/DR and EE programs. Hence, the potential DSM benefits will again be limited by this critical capability and implementation resource barrier. We do not believe this to be a viable option for the KSA.

Capability Building Options 2A and 2B – Create DSM Program Management Office

In this option, a non-permanent DSM Program Management Office (PMO) is introduced to help build and sustain DSM implementation momentum in the KSA. As we have previously described, one key limitation of DSM progress historically within the KSA has been the lack of appropriately skilled and experienced individuals to help drive implementation and results. This option addresses the gap in the organizational capacity and technical capabilities that exist in the current DSM implementation efforts. This option would inject the right level of experienced resources to drive DSM implementation.

The PMO would be staffed by qualified internal Saudi resources, external third-party contractors, or a combination of these resources. PMO staffing would depend upon the final DSM program agenda, internal resource availability and funding. In addition, to ensure timely implementation of the DSM programs, external consulting resources could be deployed to initially launch the efforts and then could be transitioned to internal Saudi resources over time.

The disadvantage of this option is that DSM implementation funding will need to account for the increased level of any external consulting resources. However, it is important to note that the PMO is not intended to be a permanent solution to DSM implementation in the KSA. One key objective of the PMO will be to help the transfer these skills, expertise and perhaps even the internal Saudi resources assigned to the PMO into SEC/Marafiq over time, hence building the fundamentals skills for a sustainable future LM/DR implementation organization.

The PMO would work closely with SEC/Marafiq and perhaps even be co-located with SEC/Marafiq. However, the PMO would not report directly to the utility. This is critical to ensure alignment of implementation objectives between each organization. The PMO's primary objective will be to drive the implementation of the DSM programs and work with utilities, third-party service providers and customers. The specific reporting line of the PMO could initially be ECRA, or any other appropriate entity such as SEEC. This capability building option is described in Figure 11-2 and Figure 11-3.

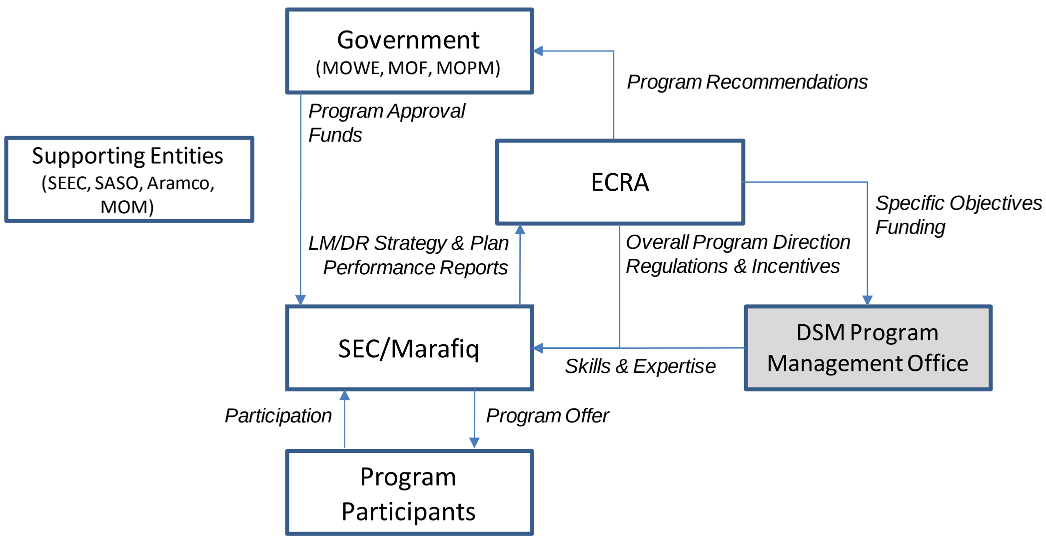

Figure 11-2: Option 2A – Create DSM Program Management Office (Reporting to ECRA)

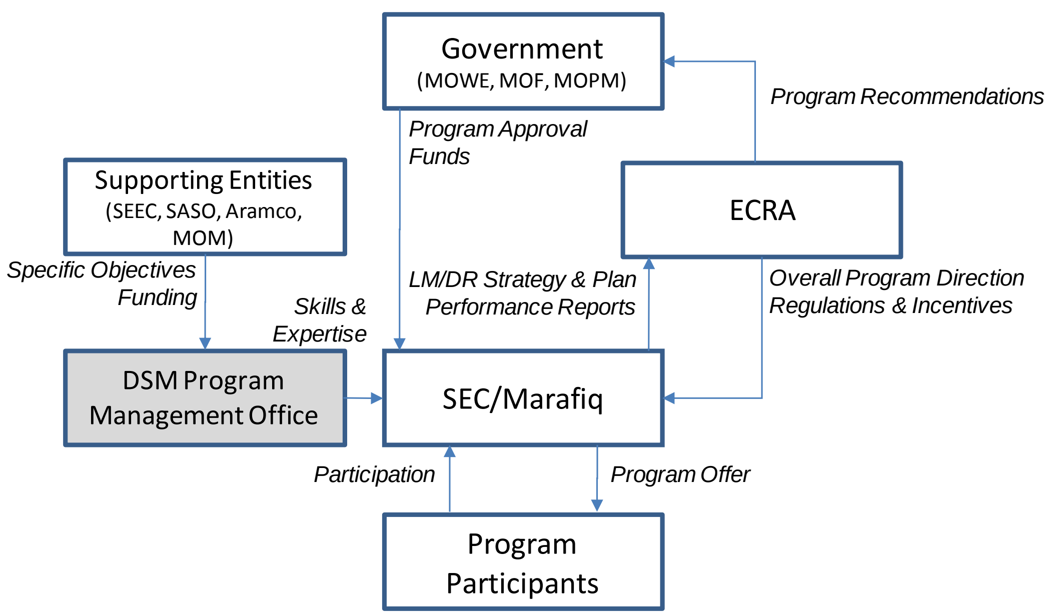

Figure 11-3: Option 2B – Create DSM Program Management Office (Reporting to SEEC)

Capability Building Option 3 – Introduce Market Enabler

In this option, a third-party energy service provider (or multiple providers) would be introduced into the market to help lead the implementation of some DSM measures in the KSA. This more open market structure would enable successful implementation DSM measures which require broad and extensive customer interactions and technical capabilities beyond those currently within SEC or Marafiq. This option would be considered a step further than Option 2 to help drive DSM implementation within the KSA.

In order to develop a sustainable DSM market within the KSA, energy service providers (ESP) will need to be indigenous to the Kingdom. Hence, one key objective of this option will be to build capabilities that would eventually make the third party entity or entities entirely Saudi-based. As we know, ESP capabilities within the KSA are also very limited. Under this option, any newly created Saudi-based ESPs would be required to partner with international ESPs with DSM expertise in an effort to transfer knowledge and skill sets. This model is being employed successfully in countries such as China, India and Thailand. The specific approach of this option can vary based on the DSM program implementation recommendations, however the goal will be to create a KSA-specific ESP infrastructure.

SEC/Marafiq would also implement a complementary portfolio of DSM measures, and the PMO in this option would provide SEC/Marafiq with the needed organizational capacity and support. In addition, the reporting line of the third-party energy service provider(s) could also initially be directly to the PMO to facilitate an easier market transition.

The disadvantage of this option is that any third-party energy service provider will need a defined incentive mechanism, potentially supported by a regulatory framework that will allow them to make the financial commitment to enter the Saudi market. While the third-party may be willing to take on market risks for a reasonable return on its DSM implementation efforts, it may be difficult for any service provider to enter a new market, such as the KSA.

Based on our experience with third-party service companies, we do not believe this is a major hurdle to overcome assuming there are clearly defined incentive mechanisms and a supportive regulatory environment. In addition, there might be existing third-party service companies with operations within the KSA that have not been directly involved in DSM activities. Depending upon DSM implementation requirements and the presence of any such third-party, the deployment of this option may not be a significant concern.

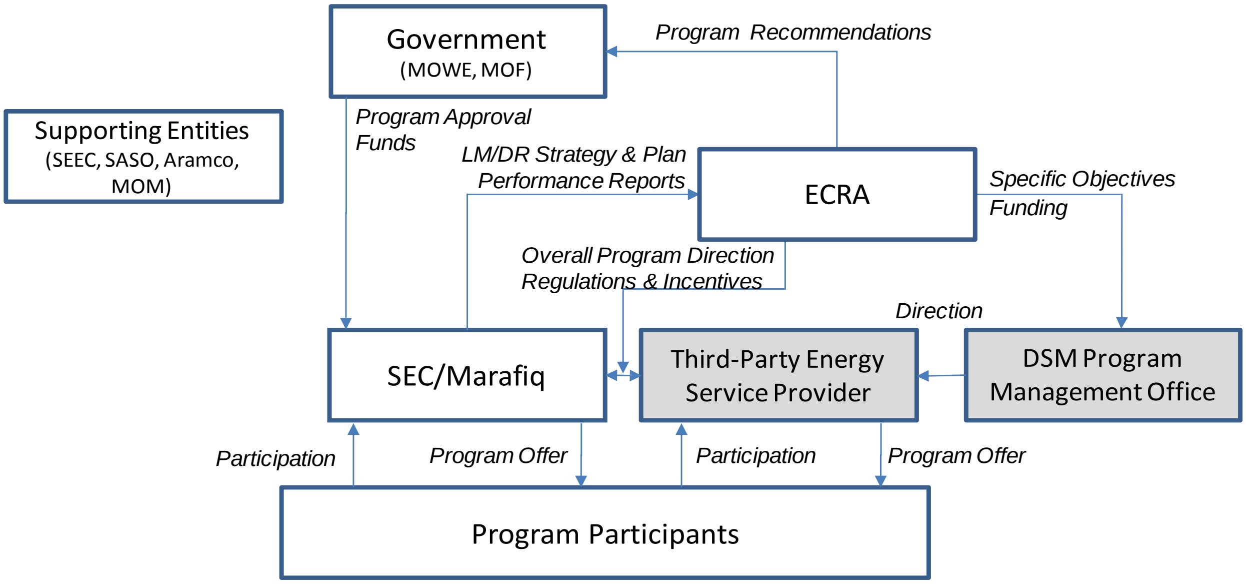

Figure 11-4: Option 3 – Introduce Market Enabler

In this chapter, we have outlined several capability building options for consideration in Saudi Arabia. While Option 1 is likely the easiest option to implement, it is also very similar to "status quo" and the least likely option to ensure success from DSM program implementation within the KSA. Option 2 is a slightly modified version of the current structure, with specific accountabilities for building capability and ensuring DSM implementation performance. Finally, Option 3 is significantly modified because it embraces more open market strategies and tactics for DSM implementation within the KSA. However, this option may require ECRA to establish specific guidelines and regulations that will encourage third-parties to enter the DSM market in the KSA. We recommend that Option 2 or Option 3 be considered to help to ensure successful DSM program implementation within the KSA.

12. SHORT TERM DSM IMPLEMENTATION PLANS

This chapter provides detailed implementation plans for the five programs that the *Brattle* team is recommending for short-term deployment in the KSA. The five programs include two that have an EE focus and three that have an LM/DR focus:

- Cooling Equipment (EE focus)
- New Buildings (EE focus)
- Direct Load Control (LM/DR focus)
- Interruptible Tariffs (LM/DR focus)
- Curtailable Load (LM/DR focus)

Each program is described in detail in the sections that follow. For each program, we offer brief outlines of the various elements that normally are considered when implementing a DSM program. These elements include:

- Plan objective
- Target markets and DSM measures
- Plan overview
- Program delivery strategies
- Timeline for implementation
- Program budget
- Market potential (including number of installations and aggregate savings)
- Cost-effectiveness analysis

The various DSM programs were assessed for cost-effectiveness drawing upon the California Standard Practice protocol for DSM economic assessment.[141] For the purposes of this study, three economic test perspectives from the protocol were applied. Each is defined below:

- The Total Resource Cost (TRC) test measures benefits and costs from the perspective of the utility and society as a whole. The benefits are the net present value of the energy and capacity saved by the measures. The costs are the net present value of all costs to implement those measures. Since electricity customers in the KSA are taken as a whole, changes in the monetary amounts that flow between them (transfer payments or in this case incentives) are ignored. Programs passing the TRC test (that is, having a B/C ratio greater than 1.0) result in a decrease in the total cost of energy services to all electric ratepayers.

- The Participant test measures the benefits and costs from the perspective of program participants as a whole. Benefits are considered to be the net present value savings that customers receive on their electric bills as a result of the implementation of the energy efficiency and demand response measures. Costs are considered to be the customer's up-front net capital costs to install the measures. If the customer receives some form of a

[141] The California Standard Practice approach is a commonly accepted methodology used throughout the world for assessing the economics of DSM measures and programs. See document titled "California Standard Practice Manual, Economic Analysis of Demand-Side Programs and Projects." October 2001.

rebate or credit as a result of participating in the DSM program, then those costs are considered as a credit to the customer and are subtracted from the customer's total capital costs. In some programs (e.g., direct load control incentives) the credit is greater than the capital costs, so the total costs can be negative.

- The Program Administrator Cost (PAC) test measures the costs and benefits from the perspective of the organization administering the program. Benefits are considered to be the net present value of the avoided energy and capacity costs resulting from the implementation of the measures. Costs are considered to be the administrative, marketing and evaluation costs resulting from program implementation along with the costs for the customer incentives. Programs passing the PAC test result in overall net benefits to the administering entity (e.g., SEEC or SEC), thus making the program worthwhile from an administration cost accounting perspective.

The cost-effectiveness analysis was performed at an aggregate level, representing the potential effects of each individual DSM program in the portfolio.

12.1. Cooling Equipment Program

The Cooling Equipment program is designed to encourage and assist residential, commercial and government end-use customers to improve the energy efficiency of their existing facilities through a dual strategy where (a) strict standards are set by the government that mandate manufacturers and equipment distributors to only sell cooling equipment that meets minimum efficiency levels and (b) incentives are offered to end-use customers at the time when equipment needs to be replaced to encourage their adoption of cooling equipment that brings about higher levels of efficiency relative to the minimum standards.

12.1.1. Plan Objective

The objective of the program is to establish government-mandated efficiency standards for cooling equipment and at the same time increase awareness of cooling energy savings opportunities that will ultimately assist customers in acting on those opportunities to decrease energy usage in residences, commercial buildings and government buildings and facilities. The program is designed for retrofit and replacement projects.

The program has several specific objectives:

- Develop minimum efficiency levels for new cooling equipment available in the KSA market.
- Increase consumers' awareness and understanding of the breadth of energy efficiency opportunities for cooling equipment in their homes and facilities.
- Make it easier for customers to adopt more energy-efficient equipment and equipment maintenance.
- Make significant contribution to attainment of KSA's energy savings goals.
- Demonstrate KSA's commitment to and confidence in the measures' performance and their ability to reduce customer energy use.

12.1.2. Target Markets and DSM Measures

Since this is structured as an equipment replacement program, the target market is generally assumed to be customers who are in need of replacing their old cooling equipment with new equipment because the latter has become non-operational. The target markets and EE measures made available for this program include the following:

- Residential (including apartment, house, flat in villa or block and villa):
    - Room air conditioners
    - Split-system air conditioners
    - Central air conditioners
- Commercial (including hotels, restaurants, malls and stores, offices, private hospitals and other):
    - Split-system AC units
    - Packaged AC systems
    - Central chillers (air-cooled, water-cooled and variable speed)
    - District cooling systems
- Government (including education, ministries, government hospitals, mosques, and military)
    - Split-system AC units
    - Packaged AC systems
    - Central chillers (air-cooled, water-cooled and variable speed)
    - District cooling systems

12.1.3. Plan Overview

Table 12-1 provides an overview of the Cooling Equipment program in terms of the estimated number of installations, the energy savings, the peak demand savings, annual expenditure, amount of carbon offset by the savings, and the benefit-cost ratios.[142]

[142] The carbon offset estimate is based on a conversion factor obtained from the Carbon Trust, a not-for-profit company based in the UK with the mission to accelerate the move to a low carbon economy. The conversion factor is based on a fuel oil energy source (which is best representative of the predominant generation fuel mix in the KSA. The factor of 0.26592 Kg CO2e per kWh is applied to the energy savings. An avoided loss factor of 10% is applied to this conversion resulting in the following factor for the calculation that appears in this table: 0.2955 Tonnes/MWh.

Table 12-1: Cooling Equipment Program Plan Overview

	2012	2016	2021
Number of Installations per Year (i.e., Number of Buildings)			
Residential	283,135	1,132,539	1,132,539
Commercial	4,612	18,450	18,450
Government	1,217	4,867	4,867
Energy Savings (GWh):			
Residential	326	4,563	11,083
Commercial	49	689	1,673
Government	41	580	1,409
GWh Total	416	5,833	14,165
Peak Demand Savings (MW)			
Residential	93	1,302	3,163
Commercial	8	112	273
Government	7	95	230
MW Total	108	1,509	3,666
Tonnes CO_2 Reduced	164,955	3,020,644	12,286,291
Annual Expenditure (Million SR)	482	2,168	1,257

Benefit/Cost Ratios

Test Perspective	KSA Energy Prices	Shadow Prices
Total Resource Cost Test	1.3	3.6
Participant Cost Test	7.2	20.1
Program Administrator Cost Test	1.6	4.4

12.1.4. Program Delivery Strategies

There will be a number of delivery strategies under the Cooling Efficiency program. Each strategy will be designed to ensure that the maximum amount of savings can be achieved as a result of the program efforts. The program will be delivered by third party energy efficiency service providers under the direction of SEEC. Effective implementation of the program will depend on all aspects of the delivery working effectively. This includes setting threshold standards that would mandate a minimum level of cooling equipment efficiency, educating customers on those products and increasing their awareness of the EE story in general, making qualifying products available, distributing information about the products and the program, promoting the program adequately, and educating those influential in making product selection and purchasing decisions. Each aspect of the delivery is highlighted in the sections below.

Equipment efficiency standards

Minimum efficiency standards for cooling equipment will be established as part of this program. The program administrator will work with the appropriate agencies within the KSA to establish the most appropriate efficiency levels to set as a minimum threshold for all cooling equipment sold in the Kingdom. For example, all room and split system air conditioners sold in the KSA would be required to have a minimum EER of 10.0 (SASO 5 Star).[143] . Any equipment vendor or manufacturer who sells equipment with efficiency levels below this minimum would be subject to criminal penalties.

Customer education and awareness campaigns

Opportunities to educate both the trade allies, who themselves are both potential participants and delivery channels, and energy consumers will include:

- Electric bill inserts and/or direct mail
- Trade publication articles on the benefits of specific measures, technologies, and diagnostic tune-ups, as well as whole facility assessments
- Trade industry meetings leveraged to include product and program education as part of them
- Workshops provided by government agencies for residential consumers and commercial and government businesses to understand how to improve energy use in their facilities
- Facility audit reports
- Local mechanical contractors (includes industry and technology experts) who meet individually with facility decision makers during outreach and project development

Consumer education will be in combined with the program awareness activities and provided through the education delivery channels. Using bill inserts, newsletters, on-line information, and direct mail customers will receive educational information regarding the benefits of and opportunities to save money on energy efficiency upgrades.

Marketing and outreach

The program will be promoted through a variety of formats. In addition to the customer education and awareness campaigns described above, program implementers would engage with various media sources for advertising initiatives on television and newspapers. The commercial TV spots would stress the importance of EE for the KSA (more generally) with region-specific spots that would stress specific conditions with various targeting strategies for residential vs. commercial customers. Newspaper spots would also be geared to various audiences (e.g., residential vs. small commercial, etc.). The marketing and outreach for larger customers would be conducted primarily through one-to-one contact between the EE implementation entity and the end-use customers.

[143] MOEW-KFUPM report CER 2321 – Study of Efficient Air Conditioning Technologies, October 2009.

Participation incentives

Customer incentives will be offered in the form of cash rebates that are intended to buy down the extra cost associated with the cooling EE measures. Because EE in general is a difficult sell in the KSA due to the low electricity prices, it is essential that the maximum customer incentives be offered in order to ensure that customers are at least indifferent between the standard efficiency cooling equipment and the high efficiency cooling equipment during the time that they are replacing old retired equipment. It is important that the incentive strategy be structured in such a way that customers start to bear some of the cost for the measures. As such, we have structured the incentives to begin phasing down after the first five years of implementation, going from 100% through 2016 to 75% of incremental cost in 2017 and 2018 and finally remaining at 50% of the incremental cost for the final three years of the plan.

12.1.5. Timeline for Implementation

Table 12-2 identifies key milestones for initiating and operating the Cooling Equipment program. The program will commence operations in 2012 and run through 2021.

Table 12-2: Cooling Equipment Program Implementation Schedule

Milestone	Timing
Secure program approval and funding source	1 January 2012
Develop detailed program plan including rollout schedule, funding plan, incentive strategy, enforcement mechanisms, marketing plan, verification plan, and support function	Q1 2012 activity; completed by 31 March 2012
Develop minimum equipment efficiency standards and enforcement provisions	Q1 2012 activity; completed by 31 March 2012
Issue tenders and select third-party program implementation contractor (PIC)	Q2 2012 activity; completed by 31 May 2012
Develop trade ally network, educate and train manufacturers, distributors and developers on the various aspects of the program and energy efficiency in general	Q2 2012 activity; completed by 31 May 2012
Launch program	1 July 2012
Program activity reporting	Monthly reports submitted to ECRA by PIC; annual reports for calendar year due 31 March of each year 2013-2021
Conduct process and impact evaluations to assess program success and to make design adjustments	Conduct every other year during the first quarter: 2014, 2016, 2018, 2020, 2022

12.1.6. Program Budget

Table 12-3 indicates the budgetary requirements for this program. The budget estimates are separated between program administration and customer incentives. To derive the costs, customer incentive amounts were determined for this program (as described above). These amounts were aggregated for the program as a whole. The program administration costs then were derived based on an assumption of 15% of the incentive costs. The elements of the program administration include the following general categories:

- Program Administrator—Includes the costs that would be borne by the entity that is administering the program (likely SEEC). Given the significant involvement of minimum equipment efficiency standards development and enforcement, the costs of other related agencies such as SASO would also be burdened against this program.
- Program implementation contractor (PIC)—Includes cost of providing the following:
  - Participant recruitment and assistance—including customers as well as equipment suppliers and contractors, technical and incentive application assistance, and pre/post-installation inspections.
  - Marketing—development of materials to explain program, direct mail, bill inserts, participation in trade shows.
  - Program-specific education—as needed with trade allies and customers at industry meetings, coordination/leveraging of workshops by collaborative resource providers, articles in trade publications, and fact sheets.
  - Incentive processing and fulfillment.
  - Coordination of enablement—includes working with the customer to define energy efficiency equipment options most suitable for their facility, coordinating installation of the selected equipment, validation and testing of equipment, and certification of equipment operational status.
  - Program monitoring and tracking—including recording and reporting of activities, providing required data for the program data tracking system and regulatory reporting, complaint resolution, and process tracking and improvements.
- Measurement and Verification (M&V)—Includes the impact and process evaluation activities conducted by an independent third party contractor other than the PIC.
- Promotion—For media advertising to promote this program.

Table 12-3: Cooling Equipment Program Budget

Cost Element	Million SR			
	2012	2016	2021	Total
Customer Incentives	419	1,885	1,093	12,469
Program Administration	63	283	164	1,870
Total	**482**	**2,168**	**1,257**	**14,339**

The annual program expenditures will be 482 million SR in the first year (2012) growing to 2.2 billion SR in 2016 and 1.3 billion SR by 2021. The cumulative expenditures would be over 14 billion SR over the time period 2012 to 2021.

12.1.7. Market Potential

The market potential for the program is comprised of two primary elements—the estimated number of participants in the program, as reflected by the number of cooling equipment installations for each year of the program and for all the years combined and the program savings, as reflected by the energy and peak demand savings for each year of the program and for all the years combined (represented in terms of GWh for energy savings and MW for peak demand reductions).

Estimated Number of Installations

The estimated number of installations of energy efficiency measures is provided in Table 12-4. The table indicates that there will be nearly 7 million high efficiency room AC units installed, with another half million split system AC units and nearly 150,000 central AC units for the residential sector. In the commercial sector, there will be nearly 150,000 high efficiency split-system AC systems, over 8,000 packaged AC systems, over 2,800 chiller systems and nearly 500 district cooling systems. For the government sector, over 30,000 split-system AC systems, nearly 7,000 packaged AC systems, over 3,000 central chillers and 261 district cooling systems.

Table 12-4: Cooling Equipment Program Number of Installations

Program Component	Number of Installations per Year (i.e., Number of Buildings)			Total Installations (all years)
	2012	2016	2021	
Residential				
Central AC	4,319	17,276	17,276	146,846
Split System AC	14,397	57,587	57,587	489,487
Room AC	203,953	815,812	815,812	6,934,401
Programmable Thermostats	60,466	241,864	241,864	2,055,846
Commercial				
Split System AC	4,278	17,111	17,111	145,443
Packaged AC System	238	951	951	8,080
Central Chillers	83	333	333	2,828
District Cooling	14	55	55	471
Government				
Split System AC	920	3,680	3,680	31,277
Packaged AC System	197	788	788	6,702
Central Chillers	92	368	368	3,128
District Cooling	8	31	31	261

Program Savings

The program-level energy and peak demand savings are reported in Table 12-5. The program is expected to save 417 GWh in the first year of operation, growing to over 14,000 GWh by 2021. Relative to the baseline energy usage, these savings represent a 0.2% reduction in 2012 and 10.4% in 2021. For peak demand, the expected peak demand reductions will be 108 MW or 0.2% of the baseline in 2012, growing to 3,666 MW or 4.9% of the baseline in 2021. In addition, approximately 4.2 million tonnes of carbon will be offset as a result of this program.

Table 12-5: Cooling Equipment Program Savings

Program Component	2012	2016	2021
Energy Savings (GWh)			
Residential	326	4,564	11,483
Commercial	49	689	1,673
Government	41	580	1,409
Total GWh	**417**	**5,833**	**14,165**
Peak Demand Reductions (MW)			
Residential	93	1,302	3,163
Commercial	8	112	273
Government	7	95	230
Total MW	**108**	**1,509**	**3,666**
Carbon Offset (Tonnes CO_2)			
Residential	96,316	1,348,430	3,274,758
Commercial	14,538	203,534	494,298
Government	12,245	171,428	416,324
Total Tonnes	**123,099**	**1,723,392**	**4,185,380**

12.1.8. Cost-Effectiveness Assessment

A program-level cost-effectiveness assessment was conducted. The following three test perspectives were assessed for this program: the total resource cost (TRC) test, the participant test and the program administrator cost (PAC) test. Table 12-6 summarizes the results of the cost-effectiveness analysis.

Table 12-6: Cooling Equipment Program Cost-Effectiveness Results

Test Perspective	KSA Energy Prices		Shadow Prices	
	Net Benefits (Million SR)	B/C Ratio	Net Benefits (Million SR)	B/C Ratio
Total Resource Cost (TRC) Test				
Residential	2,938	1.4	22,010	3.7
Commercial	253	1.3	3,132	4.1
Government	(135)	0.9	2,289	2.9
Overall	3,056	1.3	27,431	3.6
Participant Test				
Residential	9,719	7.5	28,791	20.3
Commercial	1,074	7.0	3,952	23
Government	841	4.9	3,266	16.2
Overall	11,634	7.2	36,009	20.1
Program Administrator Cost (PAC) Test				
Residential	4,426	1.7	23,498	4.5
Commercial	433	1.5	3,312	5
Government	79	1.1	2,504	3.6
Overall	4,939	1.6	29,313	4.4

The cost-effectiveness results reveal that the program has a TRC B/C ratio of 1.3 using KSA energy prices. From the PAC test perspective, the program is cost effective using the KSA energy prices at 1.6. These results are consistent with measure-level economic screening results reported in Chapter 7. However, when the shadow or market prices are used, the program appears to be far more cost effective under the TRC and PAC test perspectives. Under both energy price scenarios, the program is significantly cost effective from the participant test perspective.

12.2. NEW BUILDINGS PROGRAM

The New Buildings program is designed to accelerate the incorporation of energy efficiency in the design, construction, and operation of new, renovated or reconstructed homes and buildings in the KSA. This program will involve two major elements. The first is to step-up the implementation of the existing KSA building codes such that builders and designers know that they must plan for more efficient construction practices or be subject to fines and penalties. The second element is to offer upstream designers/builders and owner-builders educational opportunities and rebates for the installation of high efficiency end-use equipment and building envelope measures in new residential, commercial and government buildings.

Consistent with international models for new building construction,[144] this program takes a "whole building" approach, encouraging designers, builders, and developers to think of home and building performance in total, rather than in terms of the efficiency of individual components. It focuses on raising the standards of all components, from building shell through appliances and cooling equipment.

[144] The US has developed a program known as ENERGY STAR, which is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy that set specific guidelines for minimum levels of equipment efficiency and building shell measures. The program targets new home construction as well as ENERGY STAR partnerships in commercial and institutional buildings.

The program would have the following components:

- Education—teach the new home and new buildings market stakeholders, and renovation contractors and developers, about the benefits of energy-efficient designs and inform them of incentives available for the installation of an energy-efficiency shell and equipment.
- Rebates—offer rebates to builders or building owners for the incorporation of high efficiency end-use equipment and building envelope measures in new residential, commercial and government buildings; higher rebates are offered to buildings that meet higher efficiency standards.

12.2.1. Plan Objective

The objective of the program is to establish government-mandated efficiency standards for the building shell and for cooling equipment and at the same time increase awareness of energy savings opportunities that will ultimately assist customers in acting on those opportunities to ensure that energy usage will be greatly minimized for newly-constructed residences, commercial buildings and government buildings and facilities. The program is designed for new and renovation construction projects throughout the Kingdom.

The program has several specific objectives:

- Develop minimum efficiency levels for building envelope and for new cooling equipment available in the KSA market.
- Produce a permanent improvement in "standard" design practices among building designers and owners that will continue without the need for short-term incentives.
- Increase awareness and understanding of the breadth of energy efficiency opportunities for building envelope and cooling equipment in their homes and facilities.
- Make it easier for customers to adopt more energy-efficient equipment and equipment maintenance.
- Make significant contribution to attainment of KSA's energy savings goals.
- Demonstrate KSA's commitment to and confidence in the measures' performance and their ability to reduce customer energy use.

12.2.2. Target Markets and EE Measures

This program is exclusively focused on the new buildings that are being constructed in the KSA. The target markets and EE measures made available for this program include the following:

- Residential (including apartment, house, flat in villa or block and villa):
    - Room air conditioners
    - Split-system air conditioners
    - Central air conditioners
    - Programmable thermostats
    - Building shell measures (ceiling insulation, wall cavity insulation, and high efficiency windows)

- Commercial (including hotels, restaurants, malls and stores, offices, private hospitals and other):
    - Split-system AC units
    - Packaged AC systems
    - Central chillers (air-cooled, water-cooled and variable speed)
    - District cooling/central chiller plants
    - Building shell measures (ceiling insulation, duct insulation, wall cavity insulation, roof insulation, and high efficiency windows)
- Government (including education, ministries, government hospitals, mosques, and military)
    - Split-system AC units
    - Packaged AC systems
    - Central chillers (air-cooled, water-cooled and variable speed)
    - District cooling/central chiller plants
    - Building shell measures (ceiling insulation, duct insulation, wall cavity insulation, roof insulation, and high efficiency windows)

12.2.3. Plan Overview

Table 12-7 provides an overview of the New Buildings program in terms of the estimated number of installations, the energy savings, the peak demand savings, annual expenditure, amount of carbon offset by the savings, and the benefit-cost ratios. [145]

[145] The carbon offset estimate is based on a conversion factor obtained from the Carbon Trust, a not-for-profit company based in the UK with the mission to accelerate the move to a low carbon economy. The conversion factor is based on a fuel oil energy source (which is best representative of the predominant generation fuel mix in the KSA. The factor of 0.26592 Kg CO2e per kWh is applied to the energy savings. An avoided loss factor of 10% is applied to this conversion resulting in the following factor for the calculation that appears in this table: 0.2955 Tonnes/MWh.

Table 12-7: New Buildings Program Plan Overview

	2012	2016	2021
Number of Installations (i.e., Number of Buildings)			
Residential	64,349	781,411	998,341
Commercial	6,822	86,232	115,975
Government	2,552	34,683	50,996
Energy Savings (GWh):			
Residential	85	2,594	8,601
Commercial	24	731	2,526
Government	33	1,066	3,886
GWh Total	142	4,391	15,013
Peak Demand Savings (MW)			
Residential	24	740	2,455
Commercial	4	126	436
Government	6	186	679
MW Total	34	1,053	3,570
Tonnes CO_2 Reduced	41,856	1,297,252	4,435,712
Annual Expenditure (Million SR)	221	3,159	2,480

Benefit/Cost Ratios		
Test Perspective	**KSA Energy Prices**	**Shadow Prices**
Total Resource Cost Test	0.8	2.4
Participant Cost Test	3.6	10.2
Program Administrator Cost Test	1.1	3.1

12.2.4. Program Delivery Strategies

There will be a number of delivery strategies under the New Buildings program. Each strategy will be designed to ensure that the maximum amount of savings can be achieved as a result of the program efforts. The program will be delivered by third party energy efficiency service providers under the direction of SEEC. Effective implementation of the program will depend on all aspects of the delivery working effectively. This includes adopting the existing KSA building codes that stipulate minimum levels for wall and ceiling insulation and expanding the code provisions into other envelope measures such as windows and the like. In addition, the threshold standards that mandate minimum levels of cooling equipment efficiency from the Cooling Equipment program would also be included in this program. Customers would be educated about the importance of the various EE products and increasing their awareness of the EE story in general, making qualifying products available, distributing information about the products and the program, promoting the program adequately, and educating those influential in making product selection and purchasing decisions. Each aspect of the delivery is highlighted in the sections below.

Building Codes

Existing and enhanced standards for building envelope will be established for homes and buildings through this program. It may be appropriate to adopt various models practiced abroad including the International Green Construction Code (IGCC) established by the International Code Council (ICC) and the US-based ENERGY STAR home and building energy performance rating systems. The program administrator will work with the appropriate agencies within the KSA to establish the most appropriate efficiency levels to establish minimum thresholds for including ceiling and wall insulation, roof insulation and windows all cooling equipment newly-constructed buildings in the Kingdom. In addition, the minimum levels of efficiency for cooling equipment described in the Cooling Equipment program would also be mandated for newly built homes and commercial/government buildings. For example, all new homes would be required to have appropriate levels of shell insulation such that heat gains into the buildings will be minimized. Any building developer who does not construct according the code would be subject to criminal penalties. Furthermore, equipment vendors or manufacturers who sell equipment to new building owners with efficiency levels below the minimum efficiency levels would be subject to criminal penalties.

Channels for Program Delivery

Because they are the key decision makers in new home and building design, it will be advantageous for the program administrator to work "upstream"— mainly with designers, builders and developers, but also with real estate agents. By doing so, the administrator can teach these trade allies about the benefits of energy-efficient home and building designs, and inform them of the financial incentives offered for the installation of energy-efficiency equipment.

- Awareness materials should be developed through direct marketing—e.g., bill inserts, newsletters, website, broadcast and print media, direct mail; and pays the participant rebates.
- Designers, Builders, and Developers—Trades people are key decision makers for building shell and systems, and determining the appliances installed in new homes and buildings. In order for the program to be effective, the New Buildings program administrator must educate them on how and why to upgrade their building practices. Once convinced, these construction influencers can promote the program and the efficiency benefits to new homebuyers as well as to their suppliers and subcontractors. Experience from new buildings programs implemented abroad indicates they are designed to encourage builders to pass the incentives they receive for installing high-efficiency measures on to homebuyers. These trades people are both participants and delivery channels for the program.

Overview of Roles and Activities

The third-party implementation contractor(s) will have full responsibility for delivery of all aspects of the program. Responsibilities fall into several activity areas:

- Identification and recruitment of upstream market stakeholders for program participation and delivery channel activities

- Education: including development and operation of training seminars for designers, builders, and developers; development and operation of demonstration homes; and development and distribution of educational publications
- Marketing: including development and distribution of program materials in collaboration with the program administrator and upstream trades people who will be both program participants and promoters
- Rebate Processing: fulfillment house to receive, review and verify applications; and either pay or submit rebates to the program administrator for payment
- Program Performance Tracking and Improvement: including rebate submittals and payments, opportunities to improve the program
- Reporting: including reporting of program activities to meet regulatory and internal requirements, in particular progress toward program goals

The upstream market stakeholders, including the designers, builders, developers, and real estate agents will receive extensive education about energy-efficient home and commercial building construction and benefits. They will also have the following roles as delivery channels:

- Designers, builders, and developers who participate in training seminars can distinguish themselves to prospective homebuyers as qualified or certified energy-efficient providers. Ones who also receive rebates for installing rebate-eligible measures can pass some or all of these incentives along to buyers.
- Builders and real estate agents educated about the features and advantages of energy-efficient buildings will, in-turn, serve as ambassadors for the program.

Education Overview

Education is a key component of the New Buildings program. The market will change through training, education and demonstration. The program will increase confidence in the performance and benefits of increased energy efficiency (better performance, lower fuel bills, reduced maintenance, etc.). Designers and builders will be encouraged to implement more energy-efficient strategies to increase energy efficiency through the program. Emphasis on the additional benefits of comprehensive energy efficiency improvements and continual maintenance to retain savings will demonstrate an overall cost-effectiveness that can be achieved without the need for financial incentives over the longer term. Ongoing deployment of these strategies will become "standard" practice by these same designers and builders in additional projects, affecting long-term market transformation.

To accomplish this, the program will offer several forms of education:

- Training seminars will be taught by experts in specific aspects of high-efficiency building design and construction. These sessions are typically offered at no cost on an ongoing basis. In addition to teaching key principles and an understanding of the program, they provide the program implementation team with an excellent opportunity to develop strong relationships and build trust with this influential group.

- Publications with technical information, practical advice, and persuasive messages will be developed. These can be included in newsletters directed to the design/build/sales community, published in trade journals, sent in direct mail, distributed at seminars, and made available on a program website page designed for this audience.
- Demonstration homes are effective in encouraging the community's involvement. The program administrator should work with communities to set total savings goals. This demonstration program will work to incorporate the use of the existing Home Energy Rating System (HERS). Demonstration homes will also promote and educate home builders, sellers, and buyers in regards to energy efficiency measures that can be incorporated into their homes, allowing them to see different types of upgrades such as lighting, window and water heaters in operation. One of the goals will be to increase the education of builders of tract homes and real estate agents about the value of a home rating system.

Participation incentives

Customer incentives will be offered in the form of cash rebates that are intended to buy down the extra cost associated with the building envelope and cooling EE measures offered as part of this program. Because EE in general is a difficult sell in the KSA due to the low electricity prices, it is essential that the maximum customer incentives be offered in order to ensure that customers are at least indifferent between the standard efficiency cooling equipment and the high efficiency cooling equipment during the time that they are replacing old retired equipment. It is important that the incentive strategy be structured in such a way that customers start to bear some of the cost for the measures. As such, we have structured the incentives to begin phasing down after the first five years of implementation, going from 100% through 2016 to 75% of incremental cost in 2017 and 2018 and finally remaining at 50% of the incremental cost for the final three years of the plan.

12.2.5. Timeline for Implementation

Table 12-8 identifies key milestones for the New Buildings program. The program will commence operations in 2012 and run through 2021.

Table 12-8: New Buildings Program Implementation Schedule

Milestone	Timing
Secure program approval and funding source	1 January 2012
Develop detailed program plan including rollout schedule, funding plan, incentive strategy, enforcement mechanisms, marketing plan, verification plan, and support function	Q1 2012 activity; completed by 31 March 2012
Review existing KSA building codes, make appropriate adjustments and establish enforcement provisions	Q1 2012 activity; completed by 31 March 2012
Issue tenders and select third-party program implementation contractor (PIC)	Q2 2012 activity; completed by 31 May 2012
Develop trade ally network, educate and train architects, engineers, and developers on the various aspects of the program and energy efficiency in general	Q2 2012 activity; completed by 31 May 2012
Launch program	1 July 2012
Program activity reporting	Monthly reports submitted to ECRA by PIC; annual reports for calendar year due 31 March of each year 2013-2021
Conduct process and impact evaluations to assess program success and to make design adjustments	Conduct every other year during the first quarter: 2014, 2016, 2018, 2020, 2022

12.2.6. Program Budget

Table 12-9 indicates the budgetary requirements for this program. The budget estimates are separated between program administration and customer incentives. To derive the costs, customer incentive amounts were determined for this program (as described above). These amounts were aggregated for the program as a whole. The program administration costs then were derived based on an assumption of 15% of the incentive costs. The elements of the program administration include the following general categories:

- Program Administrator—Includes the costs that would be borne by the entity that is administering the program (likely SEEC). Given the significant involvement of building code development and enforcement, the costs of other related agencies such as SASO would also be burdened against this program.
- Program implementation contractor (PIC)—Includes cost of providing the following:
  - Participant recruitment and assistance—including customers as well as architects, engineers and developers, technical and incentive application assistance, and pre/post-installation inspections.

- Marketing—development of materials to explain program, direct mail, bill inserts, participation in trade shows.
- Program-specific education—as needed with trade allies and customers at industry meetings, coordination/leveraging of workshops by collaborative resource providers, articles in trade publications, and fact sheets.
- Incentive processing and fulfillment.
- Coordination of enablement—includes working with the building developer and/or directly with the customer to define energy efficiency measure options most suitable for their facility, coordinating installation of the selected equipment, validation and testing of equipment, and certification of equipment operational status.
- Program monitoring and tracking—including recording and reporting of activities, providing required data for the program data tracking system and regulatory reporting, complaint resolution, and process tracking and improvements.

- Measurement and Verification (M&V)—Includes the impact and process evaluation activities conducted by an independent third party contractor other than the PIC.
- Promotion—For media advertising to promote this program.

Table 12-9: New Buildings Program Budget

Cost Element	Million SR			
	2012	2016	2021	Total
Customer Incentives	192	2,747	2,157	17,211
Program Administration	29	412	324	2,582
Total	**221**	**3,159**	**2,480**	**19,792**

The annual program expenditures will be 221 million SR in the first year (2012) growing to 3.2 billion SR in 2016 and 2.5 billion SR by 2021. The cumulative expenditures would be nearly 20 billion SR over the time period 2012 to 2021.

12.2.7. Market Potential

Estimated Number of Installations

The estimated number of installations of energy efficiency measures is provided in Table 12-10. The table indicates that there will be over 5 million high efficiency room AC units installed, with another 368,211 split system AC units and slightly more than 110,000 central AC units for the residential sector. In addition, there would be nearly 700,000 building shell measures installed in the residential sector. In the commercial sector, there will be over 135,000 high efficiency split-system AC systems, nearly 8,000 packaged AC systems, nearly 4,000 chiller systems and over 600 district cooling systems. In addition, there would be almost 600,000 building shell measures installed in the commercial sector. For the government sector, over 40,000 split-system AC systems, over 9,000 packaged AC systems, nearly 4,000 central chillers and 630 district cooling systems. In addition, there would be nearly 250,000 building shell measures installed in the government sector.

Table 12-10: New Buildings Program Number of Installations

Program Component	Number of Installations per Year (i.e., Number of Buildings)			Total Installations (all years)
	2012	2016	2021	
Residential				
Central AC	1,100	13,356	17,063	110,463
Split System AC	3,666	44,519	56,878	368,211
Room AC	51,936	630,681	805,766	5,216,327
Programmable Thermostats	1,100	13,356	17,063	110,463
Building shell measures	6,547	79,501	101,571	676,476
Commercial				
Split System AC	1,276	16,127	21,689	135,990
Packaged AC Systems	71	896	1,205	7,555
Central Chillers	35	448	602	3,778
District Cooling	6	75	100	630
Building Shell Measures	5,434	68,687	92,378	579,219
Government				
Split System AC	373	5,067	7,450	44,248
Packaged AC Systems	80	1,086	1,596	9,482
Central Chillers	53	724	1,064	6,321
District Cooling	4	60	89	527
Building Shell Measures	2,041	27,746	40,797	242,312

Program Savings

The program-level energy and peak demand savings are reported in Table 12-11. The program is expected to save 142 GWh in the first year of operation, growing to over 15,000 GWh by 2021. Relative to the baseline energy usage, these savings represent a 0.1% reduction in 2012 and 3.9% in 2021. For peak demand, the expected peak demand reductions will be 34 MW or 0.1% of the baseline in 2012, growing to 3,570 MW or 4.8% of the baseline in 2021. In addition, approximately 4.4 million tonnes of carbon will be offset as a result of this program.

Table 12-11: New Buildings Program Savings

Program Component	2012	2016	2021
Energy Savings (GWh)			
Residential	85	2,594	8,601
Commercial	24	731	2,526
Government	33	1,066	3,886
Total GWh	**142**	**4,391**	**15,013**
Peak Demand Reductions (MW)			
Residential	24	740	2,455
Commercial	4	126	436
Government	6	186	679
Total MW	**34**	**1,053**	**3,570**
Carbon Offset (Tonnes CO_2)			
Residential	25,182	766,337	2,541,292
Commercial	7,001	215,976	746,254
Government	9,673	314,939	1,148,165
Total Tonnes	**41,856**	**1,297,252**	**4,435,712**

12.2.8. Cost-Effectiveness Assessment

A program-level cost-effectiveness assessment was conducted. The following three test perspectives were assessed for this program: the total resource cost (TRC) test, the participant test and the program administrator cost (PAC) test. Table 12-12 summarizes the results of the cost-effectiveness analysis.

Table 12-12: New Buildings Program Cost-Effectiveness Results

Test Perspective	KSA Energy Prices		Shadow Prices	
	Net Benefits (Million SR)	B/C Ratio	Net Benefits (Million SR)	B/C Ratio
Total Resource Cost (TRC) Test				
Residential	1,072	1.2	14,099	3.1
Commercial	(914)	0.6	2,667	2.0
Government	(2,341)	0.5	2,970	1.6
Overall	(2,183)	0.8	19,736	2.4
Participant Test				
Residential	6,348	5.1	19,375	13.4
Commercial	1,082	2.8	4,663	8.6
Government	1,374	2.2	6,685	6.6
Overall	8,805	3.6	30,724	10.2
Program Administrator Cost (PAC) Test				
Residential	2,629	1.5	15,656	4.0
Commercial	(304)	0.8	3,277	2.6
Government	(1,156)	0.7	4,155	2.1
Overall	1,169	1.1	23,088	3.1

The cost-effectiveness results reveal that the New Buildings program has an overall TRC B/C ratio of 0.8 using KSA energy prices. Note however that the residential sector element of the program is cost-effective with a TRC of 1.2. These results are consistent with the economic screen results, which revealed that the commercial and government building envelope measures were not cost effective from the TRC perspective using the KSA energy price avoided cost scenario. From the PAC test perspective, the program is cost effective using the KSA energy prices. Again, this result is mostly driven by the residential sector. When the shadow or market prices are used, the program appears to be cost effective under all test perspectives. Under both energy price scenarios, the program is cost effective from the participant test perspective.

12.3. Direct Load Control Program

In this program, residential and commercial/government customers agree to have their air conditioning units remotely cycled or shut down during times of high peak demand. In return, participants will receive ongoing incentives for allowing this type of outside control of their equipment.

A one-way remote switch is connected to the condensing unit of an air conditioner. When activated by a central transmitter, the switch will not allow the equipment to operate for some predetermined portion of each hour. When the condensing unit is shut down during the LM/DR event, the fan continues to operate. This allows cool air to be circulated throughout the home or building while the compressor is disabled. The operation of the switch is controlled through a digital paging network. The control period would be for over four months during the summer period June to September. The load cycling strategy encompasses a trade-off between customer comfort and program cost-effectiveness. Air conditioner cycling strategies at other utilities range from 33% to 67%. The benchmark average is a 40% cycling strategy.

12.3.1. Plan Objective

The objective of this program is to realize demand reductions from eligible residential and commercial/government customers in KSA during the peak hours. This program constitutes one of the three LM/DR programs being considered in the entire portfolio of DR programs targeted toward electricity customers in the KSA. Because of the large number of anticipated participants and expected significant market potential, the DLC program will be a major part of the LM/DR resource portfolio.

12.3.2. Target Markets and DSM Measures

The target markets and LM/DR measures made available for this program include the following:

- Residential: Customers who have central air conditioners
- Commercial: Customers who have split AC systems
- Government: Customers who have split AC systems

12.3.3. Plan Overview

Table 12-13 provides an overview of the Direct Load Control program in terms of the estimated number of installations, the peak demand savings, annual expenditure, and the benefit-cost ratios.[146]

[146] Note that since this is a LM/DR program targeting load reductions only during peak times, it is assumed there are no energy savings. This is due to the fact that in many LM/DR programs, customers will typically shift their loads from the peak periods to off-peak periods on LM/DR event days. Because there are no claimed energy savings for this program, there will be no corresponding reductions in carbon output.

Table 12-13: Direct Load Control Program Plan Overview

	2012	2016	2021
Number of Installations per Year (i.e., Number of Buildings)			
Residential	5,375	16,880	3,792
Commercial	7,985	26,572	7,230
Government	1,717	6,532	2,483
Peak Demand Savings (MW)			
Residential	13	159	201
Commercial	40	497	658
Government	36	407	464
MW Total	89	1,062	1,322
Annual Expenditure (Million SR)	39	250	234
TRC Benefit/Cost Ratio = 1.86			

12.3.4. Program Delivery Strategies

There will be a number of delivery strategies under the Direct Load Control program. Each strategy will be designed to ensure that the maximum amount of savings can be achieved as a result of the program efforts. The program will be delivered by third party energy efficiency service providers under the direction of SEC. Effective implementation of the program will depend on all aspects of the delivery working effectively.

SEC will administer the DLC program with assistance from third-party contractors for program implementation. The key elements in the implementation strategy are:

- Program staff assignment- SEC will select and assign a program manager for developing this program, post program approval by the regulatory authorities. The manager will be responsible for the final program design.
- Contract with third party implementation contractor- SEC (and other appropriate authorities) will select and contract program implementation with an outside contractor.
- IT system enablement- Outside services will be procured for enabling IT systems in order to ensure appropriate control and communication between SEC and program participants during load control events.
- Customer Recruitment: Eligible residential customers with eligible air conditioning equipment will be recruited to participate in the program.
- Switch installation and activation: Participants who sign up for the program will have a direct load control switch installed on the air conditioning compressor. After the switch is installed, its configuration is included in the control software so that it can be activated during a DR event.
- Program promotion- Different methods such as direct mail, bill inserts, trade shows and website communications could be used for customer communication and outreach.
- Customer education- Efforts to educate participants will need to be launched soon after the program design through training workshops, lectures, and seminars.

- Verification of load reduction: After installation, quality control inspections of installed direct load control switches will need to be performed. Also, load research studies to measure and verify the load reduction from switches will need to be conducted.

Customer Incentives

Participating customers will be provided with the DLC control switch free of charge. In addition, they will receive a monthly incentive in the following amounts:

- Residential customers: 450 SR/year
- Commercial customers: 900 SR/year
- Government customers: 900 SR/year

These incentive levels are comparable with incentive amounts given to participants in comparable DLC programs in the US.

Equipment Costs

The estimated costs for the equipment are as follows:

- Residential customers: 750 SR/participant
- Commercial customers: 1,313 SR/participant
- Government customers: 3,750 SR/participant

These costs are based on US experience for a comparable program.

12.3.5. Timeline for Implementation

Table 12-14 identifies key milestones for initiating and operating the Direct Load Control program. The program will commence operations in 2012 and run through 2021.

Table 12-14: Direct Load Control Program Implementation Schedule

Milestone	Timing
Secure program approval and funding source	1 January 2012
Develop detailed program plan including rollout schedule, funding plan, IT system needs (including LM/DR infrastructure design), incentive strategy, marketing plan, verification plan, and support function	Q1 2012 activity; completed by 31 March 2012
Issue tenders and select third-party program implementation contractor (PIC) and IT system vendor	Q2 2012 activity; completed by 31 May 2012
Launch program	1 July 2012
Program activity reporting	Monthly reports submitted to ECRA by PIC; annual reports for calendar year due 31 March of each year 2013-2021
Conduct process and impact evaluations to assess program success and to make design adjustments	Conduct every other year during the first quarter: 2014, 2016, 2018, 2020, 2022

12.3.6. Program Budget

Table 12-15 indicates the budgetary requirements for this program. The budget estimates are separated between program administration, equipment, and customer incentives. To derive the costs, customer incentive amounts were determined for this program (as described above). These amounts were aggregated for the program as a whole. Customer equipment costs were also derived in a similar manner. The program administration costs then were derived based on an assumption of 15% of the incentive costs. The elements of the program administration include the following general categories:

- Program Administrator—Includes the costs that would be borne by the entity that is administering the program (likely SEC).
- Program implementation contractor (PIC)—Includes cost of providing the following:
    - Participant recruitment and assistance—including customers as well as equipment suppliers and contractors, technical and incentive application assistance, and pre/post-installation inspections.
    - Marketing—development of materials to explain program, direct mail, bill inserts, participation in trade shows.
    - Program-specific education—as needed with trade allies and customers at industry meetings, coordination/leveraging of workshops by collaborative resource providers, articles in trade publications, and fact sheets.

- Coordination of enablement—includes working with the customer to define load control options, coordinating installation of two-communicating equipment, validation and testing of equipment, and certification of equipment operational status.
- Incentive processing and fulfillment.
- Program monitoring and tracking—including recording and reporting of activities, providing required data for the program data tracking system and regulatory reporting, complaint resolution, and process tracking and improvements.

- Measurement and Verification (M&V)—Includes the impact and process evaluation activities conducted by an independent third party contractor other than the PIC.
- Promotion—For media advertising to promote this program.

Table 12-15: Direct Load Control Program Budget

Cost Element	Million SR			
	2012	2016	2021	Total
Customer Incentives	11	143	197	1,238
Equipment	24	93	32	465
Program Administration	4	14	5	70
Total	**39**	**250**	**234**	**1,773**

The annual program expenditures will be 39 million SR in the first year (2012) growing to 250 million SR in 2016 and 234 million SR by 2021. The cumulative expenditures would be over 1.7 billion SR over the time period 2012 to 2021.

12.3.7. Market Potential

The market potential for the program is comprised of two primary elements—the estimated number of participants in the program, as reflected by the number of DLC installations for each year of the program and for all the years combined and the program savings, as reflected by the peak demand savings for each year of the program (represented in terms of MW for peak demand reductions).

Estimated Number of Installations

The estimated number of installations of DLC measures is provided in Table 12-16. The table indicates that there will be a total 247,740 installations over 2012-2021.

Table 12-16: Direct Load Control Program Number of Installations

Program Component	Number of Installations per Year (i.e., Number of Buildings)			Total Installations (all years)
	2012	2016	2021	
Residential	5,375	16,880	3,792	82,028
Commercial	7,985	26,572	7,230	131,794
Government	1,717	6,532	2,483	33,918

Program Savings

The program-level energy and peak demand savings are reported in Table 12-17. The program is expected to reduce peak demand by 89 MW in the first year of operation, growing to over 1,322 MW by 2021. Relative to the baseline peak demand, these savings represent a 0.2% reduction in 2012 and 1.8% in 2021.

Table 12-17: Direct Load Control Program Savings

Program Component	2012	2016	2021
Peak Demand Reductions (MW)			
Residential	13	159	201
Commercial	40	497	658
Government	36	407	464
Total MW	89	1,062	1,322
Total MW (as % of system peak)	0.2%	1.8%	1.8%

12.3.8. Cost-Effectiveness Assessment

A program-level cost-effectiveness assessment was conducted. Only the total resource cost (TRC) test was performed as the other two tests are not relevant for this program.[147]

Table 12-18 summarizes the results of the cost-effectiveness analysis.[148]

Table 12-18: Direct Load Control Program Cost-Effectiveness Results

Sector	Total Resource Cost Test (TRC)	
	Net Benefits (Million SR)	B/C Ratio
Residential	68	1.32
Commercial	322	1.56
Government	478	3.20
Overall	**868**	**1.86**

The cost-effectiveness results reveal that the program has a TRC B/C ratio of 1.86. From the PAC test perspective, the program is also cost effective with a B/C ratio of 1.86. These results are consistent with measure-level economic screening results reported in Chapter 7.

147 Note that the participant test is not relevant since participants in the DLC program bear no costs. The Program Administrator Cost test is essentially equivalent to the TRC test since all costs are paid by the program administrator.

148 Note that it was not necessary to run the Shadow Price avoided cost scenario for this program since there are no assumed energy savings, thus avoided energy costs are not used.

12.4. INTERRUPTIBLE TARIFFS PROGRAM

The program is a voluntary tariff that is designed to reduce customer demands during times of critical demand. Customers who sign up for the program are offered a lower year-round rate in exchange for allowing their loads to be interrupted during certain hours in the year when the electrical system in the KSA is peaking. Incentives will be paid with an energy credit, calculated as SR/kWh reduced below a customer specific baseline. If customers to not perform during the interruptible events, then they will be assessed a penalty at the level equal to or greater than the discounts that they received as a result of being in the tariff.

This type of LM/DR program is the most likely of the options to be implemented by a third party entity commonly known as a curtailment service provider or load aggregator. Under the aggregator scenario, a bilateral contract is established between the program administrator (likely SEC) and the aggregator for a committed amount of load. The aggregator signs up a pool of end-use electricity customers and offers the combined load reduction resource to SEC. The aggregator in turn establishes separate contractual agreements with each individual customer who signs up for the program. The contract typically specifies participation in a minimum number of events. In other words, aggregators can increase the number of program participants that choose to participate in each event through contracts, thereby increasing the potential associated with this option.

12.4.1. Plan Objective

The objective of this program is to realize demand reductions from eligible non-residential customers (e.g., commercial, government, industrial) in KSA during the peak hours. This program constitutes one of the two non-residential LM/DR programs being considered in the entire portfolio of LM/DR programs targeted toward all electricity customers in the KSA.

12.4.2. Target Markets and DSM Measures

The target market for this program will be non-residential customers (e.g., commercial, government, industrial) of a sufficient size to facilitate viable load curtailments to occur. Typically, customers with demands greater than 200 kW who are equipped with an interval meters are the best candidates for these programs.

12.4.3. Plan Overview

Table 12-19 provides an overview of the Interruptible Tariffs program in terms of the estimated number of participants, the peak demand savings, annual expenditure, and the benefit-cost ratios.[149]

[149] Note that since this is a LM/DR program targeting load reductions only during peak times, it is assumed there are no energy savings. This is due to the fact that in many LM/DR programs, customers will typically shift their loads from the peak periods to off-peak periods on LM/DR event days. Because there are no claimed energy savings for this program, there will be no corresponding reductions in carbon output.

Table 12-19: Interruptible Tariffs Program Plan Overview

	2012	2016	2021
Number of New Participants per Year (i.e., Number of Buildings)			
Commercial	4,436	14,762	4,016
Government	1,227	4,666	1,774
Industrial	99	310	72
Peak Demand Savings (MW)			
Commercial	10	135	170
Government	12	139	150
Industrial	50	605	890
MW Total	72	878	1,210
Annual Expenditure (Million SR)	18	100	75
TRC Benefit/Cost Ratio = 4.31			

12.4.4. Program Delivery Strategies

There will be a number of delivery strategies under the Interruptible Tariffs program. Each strategy will be designed to ensure that the maximum amount of savings can be achieved as a result of the program efforts. The program will be delivered by third party load aggregators under the direction of SEC. Effective implementation of the program will depend on all aspects of the delivery working effectively.

The key elements in the implementation strategy are:

- Program staff assignment: SEC will select and assign a program manager for developing this program. The program manager will be responsible for the final program designs. In addition, the program manager will manage the issuance of tenders, review prospective aggregators, and negotiate contractual terms.
- IT system enablement: IT systems must be enabled to ensure the ability to calculate and bill based on customer-specific baselines that must be calculated within each of the billing periods.
- Customer Recruitment: Because medium and large commercial, government and industrial customers will be eligible for the program, recruitment will need to appeal to the mass market in some cases, but in others more tailored approaches may be required. Bill inserts and website banners may be a possibility. For larger customers or chain accounts, communication from the customer service representatives from SEC and/or the aggregator and targeted marketing may be necessary.
- Event Notification: Once a notification strategy is in place it will be necessary to establish a means of communication with participants. Options might include auto-dial phone messages, email, notification through Auto-DR equipment, notification through PCTs, and/or notification through mass media (radio commercials).
- Program promotion: Different methods such as direct mail, bill inserts, trade shows, and website communications could be used for customer communication and outreach.

- Customer education: Efforts to educate participants, to be launched soon after the program design, may include mailed materials, website, training workshops, lectures, and seminars. Customers are likely to need extra education on the manner in which the credits and customer-specific baseline are calculated.
- Verification of load reduction: Load research studies to measure and verify the load reduction estimates calculated through the customer-specific baselines should be conducted.

Customer Incentives

Participating customers will be provided with the necessary two-way communication equipment free of charge. In addition, customers will receive an average discount of 20% off their normal tariff rate. Based on current average rates for each customer class, these discounts translate into the following amounts by sector:

- Commercial customers: 4.0 halala/kWh
- Government customers: 5.2 halala/kWh
- Industrial customers: 2.8 halala/kWh

Equipment Costs

The estimated costs for the equipment are as follows:

- Commercial customers: 1,078 SR/participant
- Government customers: 4,313 SR/participant
- Industrial customers: 21,563 SR/participant

These costs are based on US experience for a comparable program.

12.4.5. Timeline for Implementation

Table 12-20 identifies key milestones for initiating and operating the Interruptible Tariffs program. The program will commence operations in 2012 and run through 2021.

Table 12-20: Interruptible Tariffs Program Implementation Schedule

Milestone	Timing
Secure program approval and funding source	1 January 2012
Develop detailed program plan including rollout schedule, funding plan, IT system needs (including LM/DR infrastructure design), incentive strategy, marketing plan, verification plan, and support function	Q1 2012 activity; completed by 31 March 2012
Issue tenders and select third-party program implementation contractor (PIC) and IT system vendor	Q2 2012 activity; completed by 31 May 2012
Launch program	1 July 2012
Program activity reporting	Monthly reports submitted to ECRA by PIC; annual reports for calendar year due 31 March of each year 2013-2021
Conduct process and impact evaluations to assess program success and to make design adjustments	Conduct every other year during the first quarter: 2014, 2016, 2018, 2020, 2022

12.4.6. Program Budget

Table 12-21 indicates the budgetary requirements for this program. The budget estimates are separated between program administration and customer incentives. To derive the costs, customer incentive amounts were determined for this program (as described above). These amounts were aggregated for the program as a whole. Customer equipment costs were also derived in a similar manner. The program administration costs then were derived based on an assumption of 15% of the incentive costs. The elements of the program administration include the following general categories:

- Program Administrator—Includes the costs that would be borne by the entity that is administering the program (likely SEC).
- Program implementation contractor (PIC)—Includes cost of providing the following:
    - Participant recruitment and assistance—including customers as well as equipment suppliers and contractors, technical and incentive application assistance, and pre/post-installation inspections.
    - Marketing—development of materials to explain program, direct mail, bill inserts, participation in trade shows.
    - Program-specific education—as needed with trade allies and customers at industry meetings, coordination/leveraging of workshops by collaborative resource providers, articles in trade publications, and fact sheets.
    - Customer-specific contractual development and management.

- Coordination of enablement—includes working with the customer to define load control options, coordinating installation of two-communicating equipment, validation and testing of equipment, and certification of equipment operational status.
- Program monitoring and tracking—including recording and reporting of activities, providing required data for the program data tracking system and regulatory reporting, complaint resolution, and process tracking and improvements.

- Measurement and Verification (M&V)—Includes the impact and process evaluation activities conducted by an independent third party contractor other than the PIC.
- Promotion—For media advertising to promote this program.

Table 12-21: Interruptible Tariffs Program Budget

Cost Element	Million SR			
	2012	2016	2021	Total
Customer Incentives	3	41	54	344
Equipment	11	44	17	223
Program Administration	4	15	5	73
Total	**18**	**100**	**76**	**640**

The annual program expenditures will be 18 million SR in the first year (2012) growing to 100 million SR in 2016 and 76 million SR by 2021. The cumulative expenditures would be around 640 million SR over the time period 2012 to 2021.

12.4.7. Market Potential

The market potential for the program is comprised of two primary elements—the estimated number of participants in the program, as reflected by the number of enrolled participants for each year of the program and for all the years combined and the program savings, as reflected by the peak demand savings for each year of the program (represented in terms of MW for peak demand reductions).

Estimated Number of Enrolled Participants

The estimated number of enrolled participants is provided in Table 12-22. The table indicates that there will be nearly 100,000 enrolled participants over the periods 2012-2021.

Table 12-22: Interruptible Tariffs Program Number of Enrollments

Program Component	Number of Enrollments per Year (i.e., Number of Buildings)			Total Enrollments (all years)
	2012	2016	2021	
Commercial	4,436	14,762	4,016	73,219
Government	1,227	4,666	1,774	24,227
Industrial	99	310	72	1,515
Total Enrolled	**5,762**	**19,738**	**5,862**	**98,961**

Program Savings

The program-level energy and peak demand savings are reported in Table 12-23. The program is expected to reduce peak demand by 72 MW in the first year of operation, growing to over 1,210 MW by 2021. Relative to the baseline peak demand, these savings represent a 0.1% reduction in 2012 and 1.6% in 2021.

Table 12-23: Interruptible Tariffs Program Savings

Program Component	2012	2016	2021
Peak Demand Reductions (MW)			
Commercial	10	135	170
Industrial	50	605	890
Government	12	139	150
Total MW	72	878	1,210
Total MW (as % of system peak)	**0.1%**	**1.5%**	**1.6%**

12.4.8. Cost-Effectiveness Assessment

A program-level cost-effectiveness assessment was conducted. Only the total resource cost (TRC) test was performed as the other two tests are not relevant.[150] Table 12-24 summarizes the results of the cost-effectiveness analysis.[151]

Table 12-24: Interruptible Tariffs Program Cost-Effectiveness Results

Sector	Total Resource Cost Test (TRC)	
	Net Benefits (Million SR)	B/C Ratio
Commercial	141	2.43
Industrial	993	7.71
Government	104	1.81
Overall	**1,238**	**4.31**

The cost-effectiveness results reveal that the program has an overall TRC B/C ratio of 4.31. This means that the program appears to be very cost-effective and should produce significant net benefits to the KSA if implemented. These results are consistent with measure-level economic screening results reported in Chapter 7.

12.5. CURTAILABLE LOAD PROGRAM

Under the Curtailable Load program, eligible customers agree to reduce demand by a specific amount or curtail their consumption to a pre-specified level. In return, they will be compensated in one of two ways. Either they will receive a capacity credit or they will receive a one-time lump sum payment. The capacity payment is the typical incentive structure in the industry and is

150 Note that the participant test is not relevant since participants in the DLC program bear no costs. The Program Administrator Cost test is essentially equivalent to the TRC test since all costs are paid by the program administrator.

151 Note that it was not necessary to run the Shadow Price avoided cost scenario for this program since there are no assumed energy savings, thus avoided energy costs are not used.

a fixed incentive payment that would be expressed as SR/kW-month or SR/kW-year that is paid regardless of the number of actual curtailment events each year. The amount of the capacity payment may vary with the load commitment level. The idea is to provide the customer with an up-front payment that is equal to the net present value of some number of capacity payments, say five years. However, in order to receive the lump-sum the customer must invest that payment in energy-efficient solutions for its business.

Customer loads enrolled in the Curtailable Load program represent a firm resource and can be counted toward installed potential capacity requirements by SEC or the new system operator once the electric industry is fully restructured in the KSA. Because load reductions must be of firm resource quality, curtailment is mandatory and stiff penalties are assessed for under-performance or non-performance.

Typically, industrial customers are the most able to participate in a program such as this. They generally leverage their existing automation technologies to enable their response to curtailment events. Using existing process automation systems allow customers to pre-program their responses to events to include any number of end-uses as appropriate for their specific facility including, but not limited to cooling, water heat, lighting, motors, pumps, or other processes. In addition to the capacity or lump-sum payment, customers would receive an incentive to install enabling technologies such as automated demand response.

12.5.1. Plan Objective

The objective of this program is to realize demand reductions from eligible industrial customers in the KSA during the peak hours. This program constitutes one of the two non-residential LM/DR programs being considered in the entire portfolio of LM/DR programs targeted toward all electricity customers in the KSA.

12.5.2. Target Markets and DSM Measures

The target market for this program will be industrial customers of a sufficient size to facilitate viable load curtailments to occur. Typically, customers with demands greater than 200 kW who are equipped with an interval meters are the best candidates for these programs.

12.5.3. Plan Overview

Table 12-25 provides an overview of the Curtailable Load program in terms of the estimated number of installations, the peak demand savings, annual expenditure, and the benefit-cost ratios.[152]

[152] Note that since this is a LM/DR program targeting load reductions only during peak times, it is assumed there are no energy savings. This is due to the fact that in many LM/DR programs, customers will typically shift their loads from the peak periods to off-peak periods on LM/DR event days. Because there are no claimed energy savings for this program, there will be no corresponding reductions in carbon output.

Table 12-25: Curtailable Load Program Plan Overview

	2012	2016	2021
Number of Installations per Year (i.e., Number of Buildings)			
Industrial	80	248	58
Peak Demand Savings (MW)			
Industrial	40	484	712
MW Total	**40**	**484**	**712**
Annual Expenditure (Million SR)	**10**	**100**	**136**
TRC Benefit/Cost Ratio = 1.93			

12.5.4. Program Delivery Strategies

There will be a number of delivery strategies under the Curtailable Load program. Each strategy will be designed to ensure that the maximum amount of savings can be achieved as a result of the program efforts. The program will be delivered by third party load aggregators under the direction of SEC. Effective implementation of the program will depend on all aspects of the delivery working effectively.

The key elements in the implementation strategy are:

- Program staff assignment: SEC will select and assign a program manager for developing this program. The program manager will be responsible for the final program designs. In addition, the program manager will manage the issuance of tenders, review prospective aggregators, and negotiate contractual terms.
- IT system enablement: IT systems must be enabled to ensure the ability to calculate and bill based on customer-specific baselines that must be calculated within each of the billing periods.
- Customer Recruitment: Because large industrial customers will be eligible for the program, recruitment will need to be tailored such that customer service representatives from SEC and/or the aggregator will be making calls to customers on a one-on-one basis to market the program.
- Event Notification: Once a notification strategy is in place it will be necessary to establish a means of communication with participants. Options might include auto-dial phone messages, email, and potentially through Auto-DR equipment.
- Program promotion: Different methods such as direct mail, bill inserts, trade shows, and website communications could be used for customer communication and outreach.
- Customer education: Efforts to educate participants, to be launched soon after the program design, may include mailed materials, website, training workshops, lectures, and seminars. Customers are likely to need extra education on the manner in which the credits and customer-specific baseline are calculated.
- Verification of load reduction: Load research studies to measure and verify the load reduction estimates calculated through the customer-specific baselines should be conducted.

Customer Incentives

Participating customers will be provided with the necessary two-way communication equipment free of charge. In addition, customers will receive a monthly capacity payment for making their loads available for the program. The capacity payment will be set based on the avoided capacity costs to ensure program cost effectiveness. Based on our analysis of the avoided capacity costs coupled with DR program experience from abroad, we have set a capacity incentive amount of 187.5 SR/kW-year.

Equipment Costs

The estimated costs for the enablement equipment needed for customers to effectively participate in the program are 21,563 SR/participant. These costs are based on US experience for a comparable program.

12.5.5. Timeline for Implementation

Table 12-26 identifies key milestones for initiating and operating the Curtailable Load program. The program will commence operations in 2012 and run through 2021.

Table 12-26: Curtailable Load Program Implementation Schedule

Milestone	Timing
Secure program approval and funding source	1 January 2012
Develop detailed program plan including rollout schedule, funding plan, IT system needs (including LM/DR infrastructure design), incentive strategy, marketing plan, verification plan, and support function	Q1 2012 activity; completed by 31 March 2012
Issue tenders and select third-party program implementation contractor (PIC) and IT system vendor	Q2 2012 activity; completed by 31 May 2012
Launch program	1 July 2012
Program activity reporting	Monthly reports submitted to ECRA by PIC; annual reports for calendar year due 31 March of each year 2013-2021
Conduct process and impact evaluations to assess program success and to make design adjustments	Conduct every other year during the first quarter: 2014, 2016, 2018, 2020, 2022

12.5.6. Program Budget

Table 12-27 indicates the budgetary requirements for this program. The budget estimates are separated between program administration and customer incentives. To derive the costs, customer incentive amounts were determined for this program (as described above). These amounts were aggregated for the program as a whole. Customer equipment costs were also derived in a similar manner. The program administration costs then were derived based on an assumption of 15% of the incentive costs. The elements of the program administration include the following general categories:

- Program Administrator—Includes the costs that would be borne by the entity that is administering the program (likely SEC).
- Program implementation contractor (PIC)—Includes cost of providing the following:
    - Participant recruitment and assistance—including customers as well as equipment suppliers and contractors, technical and incentive application assistance, and pre/post-installation inspections.
    - Marketing—development of materials to explain program, direct mail, bill inserts, participation in trade shows.
    - Program-specific education—as needed with trade allies and customers at industry meetings, coordination/leveraging of workshops by collaborative resource providers, articles in trade publications, and fact sheets.
    - Customer-specific contractual development and management.
    - Coordination of enablement—includes working with the customer to define load control options, coordinating installation of two-communicating equipment, validation and testing of equipment, and certification of equipment operational status.
    - Program monitoring and tracking—including recording and reporting of activities, providing required data for the program data tracking system and regulatory reporting, complaint resolution, and process tracking and improvements.
- Measurement and Verification (M&V)—Includes the impact and process evaluation activities conducted by an independent third party contractor other than the PIC.
- Promotion—For media advertising to promote this program.

Table 12-27: Curtailable Load Program Budget

Cost Element	Million SR			
	2012	2016	2021	Total
Customer Incentives	8	91	133	827
Equipment	0.8	2.8	0.8	13.4
Program Administration	2	7	1.9	33.6
Total	**11**	**101**	**136**	**874**

The annual program expenditures will be 11 million SR in the first year (2012) growing to 101 million SR in 2016 and 136 million SR by 2021. The cumulative expenditures would be almost 874 million SR over the time period 2012 to 2021.

12.5.7. Market Potential

The market potential for the program is comprised of two primary elements—the estimated number of participants in the program, as reflected by the number of DLC installations for each year of the program and for all the years combined and the program savings, as reflected by the peak demand savings for each year of the program (represented in terms of MW for peak demand reductions).

Estimated Number of Enrollments

The estimated number of enrolled participants in the program is provided in Table 12-28. The table indicates that there will be a total of 1,212 enrolled customers over the period 2012-2021.

Table 12-28: Curtailable Load Program Number of Enrollments

Program Component	Number of Enrollments per Year (i.e., Number of Buildings)			Total Enrollments (all years)
	2012	2016	2021	
Industrial	80	248	58	1,212

Program Savings

The program-level energy and peak demand savings are reported in Table 12-29. The program is expected to reduce peak demand by 40 MW in the first year of operation, growing to over 712 MW by 2021. Relative to the baseline peak demand, these savings represent a 0.1% reduction in 2012 and 1% in 2021.

Table 12-29: Curtailable Load Program Savings

Program Component	2012	2016	2021
Peak Demand Reductions (MW)			
Total MW	40	484	712
Total MW (as % of system peak)	0.1%	0.8%	1.0%

12.5.8. Cost-Effectiveness Assessment

A program-level cost-effectiveness assessment was conducted. Only the total resource cost (TRC) test was performed as the other two tests are not relevant.[153]

Table 12-30 summarizes the results of the cost-effectiveness analysis.[154]

Table 12-30: Curtailable Load Program Cost-Effectiveness Results

Sector	Total Resource Cost Test (TRC)	
	Net Benefits (Million SR)	B/C Ratio
Industrial	440	1.93

153 Note that the participant test is not relevant since participants in the DLC program bear no costs. The Program Administrator Cost test is essentially equivalent to the TRC test since all costs are paid by the program administrator.

154 Note that it was not necessary to run the Shadow Price avoided cost scenario for this program since there are no assumed energy savings, thus avoided energy costs are not used.

The cost-effectiveness results reveal that the program has an overall TRC B/C ratio of 1.93. This means that the program appears to be cost-effective. These results are consistent with measure-level economic screening results reported in Chapter 7.

13. DSM PLANS FOR THE MEDIUM TERM

In addition to the DSM programs that are ready for implementation in the short term, there are also a number of attractive opportunities for medium term deployment. These programs generally consist of measures that are likely to be cost-effective, but for which there is greater uncertainty around their potential adoption, impacts, and benefits. For these programs, market research and piloting are needed before deployment on a large scale. The programs are:

- Dynamic pricing
- Information
- Automating technologies
- Water pumping demand response
- Residential appliances
- Efficient lighting

This chapter provides an overview of each program and the impacts that they could be expected to feasibly produce in the KSA. Those program descriptions are followed by a discussion of general guidelines for establishing pilots to further explore whether they should be offered to customers on a larger scale.

13.1. DYNAMIC PRICING

Overview

A dynamic pricing program would provide each customer segment with a rate that more accurately reflects the true price of electricity. The objectives are to encourage load reductions during times when it is most costly to generate electricity and to provide a more economically efficient price signal to customers, thus removing the subsidies that are embodied in today's flat rates. For the purposes of this chapter, the term dynamic pricing is used loosely. It applies not only to the family of rates with a "dispatchable" price signal (typically only known a day or less in advance) but also includes rates such as TOU pricing and seasonal pricing. It is intended to encompass any new, innovative rate design that could be used to accomplish the KSA's load shaping objectives.

There are seven basic steps to developing and deploying a dynamic pricing program:

Step 1: Understand the impacts of today's rates
Before beginning the transition to innovative rates, the KSA must first focus on understanding the impacts of today's rates. This would include load impact evaluations of the tiered and TOU rates that currently are in place. This would also involve conducting focus groups, interviews, and/or surveys to understand customer perceptions of the rates.

Step 2: Develop a consistent and comprehensive set of ratemaking objectives
First, stakeholders must identify ratemaking objectives that are designed to advance the KSA's overall load shaping strategy and to be consistent with other policy goals. It will be important to ensure that the ratemaking objectives do not conflict. There is not a single rate that can

accomplish all goals. Also consider developing a second tier of objectives that would be specific to individual customer classes. Initiating internal focus groups and customer interviews would be one way for beginning this dialogue.

Step 3: Identify the menu of possible new rate options

Develop a deeper internal knowledge base of the potential future rate options that could be provided. This includes researching innovative rate designs that are currently being examined by other utilities as well as surveying ongoing experimental pricing pilots and AMI filings. In conducting this review, consider the distinguishing characteristics of the various rate forms and screen out any options that are entirely infeasible or not in line with the KSA's larger policy goals.

Step 4: Perform preliminary assessment of potential impacts

For each customer class of interest, develop illustrative rate designs using real system data. The potential impacts of these rates should be simulated using the best available models tailored to KSA's system conditions. Sensitivity analysis should be performed through the course of these simulations to capture the range of uncertainty in the projections. Ultimately, use the simulations to develop a preliminary strategy for the pricing transition and to narrow down the range of potential rate offerings.

Step 5: Conduct preliminary market research

In conducting market research, survey the national experience with innovative rate design and develop a list of "lessons learned" through recent pricing pilots. This includes re-examining the results of the TOU pilot to build off of that experience. Then, conduct primary market research to understand customer reactions to the rate designs, through interviews, surveys, and focus groups. This will serve as a departure point for beginning the customer education process.

Step 6: Conduct innovative pricing pilots

With an understanding of the various innovative pricing options and their potential impacts, the next step is to conduct pilots. First, establish objectives for the pilot. Then, determine the final rates to be tested in the experimental pricing pilot. The number of customers to be included in the treatment and control groups will need to be defined in a way that will provide statistically significant results. The sampling plan should be designed to ensure that the participants are representative of the KSA's customer base. Then, identify data to be collected through the pilot, including demographic characteristics of the participants and hourly load data. Final steps are to develop customer recruiting instruments for the pilot and to develop a schedule for pilot implementation. More detailed guidelines for developing, implementing, and evaluating pilots are provided later in this chapter.

Step 7: Full-scale deployment of innovative rates

Upon evaluating the pilot results, identify the rate types to be offered to each customer class. The appropriate rate deployment plan (voluntary, default, mandatory) will also need to be determined for each class. Finally, it will be necessary to identify key barriers to adoption of the new rates through focus groups and stakeholder interviews, and to develop a strategic approach to addressing the barriers before, during, and after rate deployment. Coordination between the utilities, customer representatives, and ECRA will be essential.

Market Potential

As discussed above, there are many ways in which the pricing program could be rolled out to customers (different rate options, voluntary versus default deployment, etc). To approximate the market potential for this program, consider a CPP rate that is the default rate offering for industrial, commercial, and government customers, and a voluntary rate for residential customers. Assuming the rate is fully rolled out to all customers and achievable levels of enrollment are reached by 2021, then the aggregate peak impact that could be expected from this program is 2,400 MW.[155]

13.2. INFORMATION

Overview

The objective of an information program is to provide residential customers with new information about their energy consumption patterns, which in turn would encourage them to consume less particularly during more expensive times of day. The information could be provided via technology, such as an in-home display that conveys real-time data on instantaneous power consumption and its cost to the customer. Or the information could be accessed through a website that shows the customer's historical hourly consumption pattern (assuming the customer has a smart meter). Another option is to present information on monthly consumption as a bill insert, with a comparison of where that ranks in terms of efficiency relative to similarly situated neighbors.

A key implementation question will be which of these options to provide. Market research, surveys, and focus groups will help to indicate those technologies and programs that customers are most likely to be interested in. Conversations with companies that develop the technologies and provide program services will offer more information about the functionality and cost of each option.[156] An assessment of all of these factors will help to narrow down the list of options to be tested further through experimental pilots.

Information pilots can be combined with pricing pilots to test the combined impact of both options. In fact, some information technologies are designed specifically to alert customers of the higher priced periods of a dynamic rate (for example, an orb that glows different colors depending on the current electricity price). Therefore, when developing a pilot to test various pricing treatments, consider including information treatments as well.

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[155] All program impact estimates reflect adjustments to account for overlap across programs. For example, the amount of load eligible to be reduced through a dynamic pricing program has been derated to account for the impacts of other energy efficiency programs. Participation rates are modified to prohibit dual enrollment in LM/DR programs.

[156] Examples of in-home display manufacturers are Blueline and OpenPeak. Examples of companies developing web portals are Microsoft and Google. OPower is the leading firm providing social norming programs to electric utilities.

Market Potential

Multiple information measures could be offered to customers simultaneously, as each provides different insights about energy consumption. One could envision a program that includes all three elements described above: a social norming measure (which would be provided to all customers), an advanced web portal (which would be provided to all customers with internet access), and an in-home display measure (which would be purchased by the customer on a voluntary basis). By 2021, the incremental peak savings could be 1,200 MW.

13.3. AUTOMATING TECHNOLOGIES

Overview

The objective of an automating technology program is to provide customers with equipment that will automatically reduce their consumption at various end uses during times of high electricity prices. These technologies are typically only offered in conjunction with a time-varying rate, since that provides a strong financial incentive to purchase the technology. The applicable technology depends on the customer segment, with residential and small commercial customers using PCTs (smart thermostats) and large commercial and industrial customers using Auto-DR. The technologies have been shown boost price responsiveness by providing an incremental peak reduction that would not have been achieved through pricing alone. A common approach taken by utilities in other regions is to offer PCTs for free to customers that are enrolled in dynamic pricing, and often to provide an additional incentive payment for installing the technology. Rebates are typically also offered for installing Auto-DR systems, but due to the higher cost of this technology, it is not usually fully covered by the utility or other implementation organization.

Many of the same implementation questions that have already been raised will also apply to this program. To what extent would customers be willing to adopt and install these technologies? What are the features of the technologies that are most attractive to customers (e.g., an "override" option, or a visual display of realtime electricity consumption on the thermostat)? Will these technologies provide the same incremental benefit in the KSA as they have exhibited in other regions of the world? These are all unanswered questions that can be addressed through similar market research activities, including customer surveys and experimental pilots. The automating technology treatments of the pilot should be coupled with various combinations of dynamic rates and information options in order to estimate the level of interaction across the measures.

Market Potential

The market potential for automating technologies can be established by assuming that a reasonable percentage of participants in dynamic pricing would also adopt the technology. This would be done on a voluntary basis with financial incentives being established by the utility or other party responsible for implementation. Assuming AMI and dynamic pricing were fully deployed by 2021, the incremental impact of offering this program could be 300 MW of peak reduction.

13.4. WATER PUMPING DEMAND RESPONSE

Overview

The goal of a water pumping program would be to create a partnership between SEC and SWCC/NWC to reduce water pumping load during times of system emergencies or high costs. For SWCC it may be possible to simply schedule planned maintenance around peak times when load reductions are needed by SEC. Some key program design and implementation questions include:

- *Amount of load curtailment:* What is the level of load curtailment that SWCC can agree to provide when needed? With these programs, this is often a pre-specified number that is written into the program contract and incorporated into the utility's planning procedures.

- *Incentives:* What would be the payment to SWCC and NWC for providing the agreed upon amount of load curtailment? This payment should not be higher than the cost of the alternative option, which is to build new peaking capacity to serve peak demand.[157]

- *Penalties:* If SWCC does not provide the agreed upon level of load curtailment, what financial penalties will be enforced? Typically, a "cushion" is built into the contract, so that SWCC would not be penalized if they came within some reasonable range of the amount. In California, the Department of Water Resources is not penalized as long as it provides at least half of the amount.

- *Applicable window of time:* What are the hours of the day when SEC would be allowed to ask for load reductions, and for what duration? The operations departments from SEC and SWCC would need to get together to determine the window of time that is likely to include emergency events but also does not create operational challenges for SWCC.

- *Allowed number of events:* How often will SEC be able to ask SWCC to reduce load? As the number of events increases, the cost to SWCC in terms of reduced productivity will also increase.

- *Notification time:* How far in advance will SEC notify SWCC of the need for load curtailment? Greater notification time will be easier for SWCC to manage operationally, but will provide less flexibility to SEC for addressing unexpected system events.

There will be interdependencies in the answers to these questions. For example, the amount of load that SWCC is willing to curtail will partly be a function of the incentive payment and the operational restrictions on when and how often the program can be used by SEC. Because this program would be a bilateral agreement between SEC and SWCC, the answers to these questions must be negotiated between those two parties. The next step in designing this program is to

[157] Note that SWCC and NWC may not need an incentive payment for participation in the water pumping load management program since they are government entities.

bring together the right people from both organizations and discuss these issues to determine what would be the most mutually beneficial program design.

Market Potential

It is difficult to estimate the market potential for this program without having more focused discussions with SWCC engineers about the amount of load curtailment that is achievable. It should be noted that the load associated with moving water from Al Jubail to Riyadh is 300 MW alone, so there is certainly enough potential in this program to make it worthy of further exploration, particularly given the efficiencies of being able to establish a load curtailment contract with a single large customer.

13.5. Efficient Appliances

Overview

The Efficient Appliances program is a retrofit program designed to increase the penetration of high efficiency appliance measures in homes of KSA residential and commercial customers. The program would enable the adoption of these energy-efficiency measures by offering incentives that help the customer offset extra costs for the purchase and installation of high efficiency equipment for household and commercial appliances.

The target market for the Efficient Appliances program is residential and commercial refrigeration customers throughout the KSA and, in particular, those customers with existing equipment that needs replacing or who can be persuaded to replace early. This includes customers in existing homes, villas and multi-family apartments that are either replacing existing equipment or are purchasing equipment for the first time. In addition, grocery stores and other commercial buildings with refrigeration systems would be targeted. Both owners and renters would be eligible to participate in the program.

These programs are often delivered through cash rebates that are typically paid in a prescriptive format. The rebate-eligible measures are proven technologies about which customers should be able to ultimately find supporting information. Customers are typically familiar with cash-back rebates from other types of purchases they make, and the itemized list of included measures provides the program administrator the opportunity to strengthen relationships with upstream suppliers and influence stocking decisions.

Examples of measures targeted in this program would include the following:

- Clothes washer
- Dishwasher
- Range and oven
- Refrigerator/freezer
- Commercial refrigeration systems

Market Potential

The market potential for the Efficient Appliance program is presented in Table 13-1. Because the program was represented in the second tier, for the medium term, implementation was not anticipated to be started for at least 5 years. In the interim, it is recommended that investigations be done on these measures to obtain a more complete and KSA-specific assessment of their economic viability and market potential. However, based on the preliminary market assessment, the program has a market potential of 2,015 GWh by 2021, which represents a 0.5% reduction in the baseline forecast. For peak demand, the expected market potential savings is 348 MW, which represents a 0.5% reduction in the baseline peak load. The program will realize a 595,363 tonne reduction in carbon output by 2021.

Table 13-1: Residential Appliance Program Market Potential

Parameter	2021
Energy Savings (GWh)	2,015
Peak Demand Savings (MW)	348
Tonnes CO_2 Reduced	595,363

13.6. EFFICIENT LIGHTING

Overview

The program is designed to encourage and assist residential, commercial and government customers in improving the energy efficiency of their lighting systems through a broad range of energy efficiency measures. This program would offer prescriptive incentives to customers who install high-efficiency lighting equipment and engages equipment suppliers and contractors to promote the incentive-eligible equipment.

The program has the following components, to accommodate the variety of customer needs and facilities in this sector:

- Prescriptive Rebates—deemed per-unit savings for itemized measures; easy and appropriate for most of the lighting measures, which tend to be low-cost and simple;
- Quick and easy incentive application for measures with known and reliable energy savings. No pre-approval required;
- Customers purchase and install qualified products from retailers and/or contractors;
- The prescriptive incentives are cash-back rebates that generally cover a portion of the incremental cost of the qualifying energy efficiency measures; that is, the cost premium of qualifying models over less-efficient models available.

Examples of measures that receive prescriptive incentives in this program are:

- Compact fluorescent lamps (CFL)
- T8 lamps and fixtures
- LED lamps

- Fluorescent, high-bay fixtures
- LED lamps
- Metal halide lighting
- Municipal streetlighting – Metal halide
- Municipal streetlighting – High pressure sodium
- Municipal streetlighting – LED

Market Potential

The market potential for the Efficient Lighting program is presented in Table 13-2. Because the program was represented in the second tier, for the medium term, implementation was not anticipated to be started for at least 5 years. In the interim, it is recommended that investigations be done on these measures to obtain a more complete and KSA-specific assessment of their economic viability and market potential. However, based on the preliminary market assessment, the program has a market potential of 10,390 GWh by 2021, which represents a 2.7% reduction in the baseline forecast. For peak demand, the expected market potential savings is 1,822 MW, which represents a 2.4% reduction in the baseline peak load. The program will realize a 3.1 million tonne reduction in carbon output by 2021.

Table 13-2: Efficient Lighting Program Market Potential

Parameter	2021
Energy Savings (GWh)	10,390
Peak Demand Savings (MW)	1,822
Tonnes CO_2 Reduced	3,068,836

13.7. Guidelines for Developing Experimental Pilots

The important next step for most of the programs described in this chapter is to conduct market research and experimental pilots. Particularly with new and innovative approaches to DSM, it is rare that a program would be rolled out without first evaluating its effectiveness with a smaller yet representative sample of customers. Based on experience working with utilities to design, implement, and evaluate these pilots, we have observed that there are a few ways to conduct them well, and many ways in which they can go wrong. For the results of a pilot to be capable of being generalized to the entire service area, it is necessary that the pilot follow the well-established principles of experimental design. The salient ones are summarized below.

13.7.1. Internal and External Validity of the Pilot Results

To be credible and useful to policy makers, pilot programs need to have both internal and external validity. "Internal validity" means that a cause and effect relationship can be established between the various treatments being tested and the variables of interest such as peak demand and overall energy consumption. The effect of all other variables needs to be purged. "External validity" means that the pilot results can be extrapolated to the population of interest. Both require careful design although it is generally easier to ensure internal validity than to ensure external validity.

To ensure *internal validity*, the “gold standard” of pilot design stipulates that every treatment that is being tested should also have a control associated with it so that a scientifically valid “but for” world can be constructed from which deviations can be successfully measured. In other words, cause-effect relationships cannot be inferred with any precision and any conclusions derived from the pilot may be subject to the charge that they simply measure spurious correlation. It is also likely that genuine cause-effect relationships (*e.g.*, higher prices lead to lower usage by X percent) may not be measured accurately because other factors such as a changing economy or weather may obscure the true relationship. The best way to create a “but for” environment is to select a matching group of customers who can serve as a proxy for the behavior of the treatment group customers in the absence of a treatment. In addition, to further anchor the measurements, it is best to have pre-treatment data on both the control and treatment groups as well as the treatment-period data on both groups of customers.

In the past, pilots have been carried out without matching control groups and sometimes with no control groups at all. Others have been conducted with control groups but no pre-treatment measurements. All such inadequacies impair the internal validity of the pilot in varying degrees. Without a control group in the design, it is not possible to control for non-treatment variables that change between the pre-treatment and treatment periods (such as the economy, or general changes in attitudes toward energy use brought about by other exogenous factors). Without pre-treatment data, it is difficult to determine if the treatment and control groups were comparable to each other before the treatment was introduced. If systematic pre-treatment differences exist, these may indicate a self-selection bias in the sample that needs to be dealt with.

Pilots must also have *external validity* so that their conclusions are transferable to a real world setting. In the case of a behavior-based program, it will be useful to know if such programs will ultimately be offered on a universal basis, a default basis with opt-out provisions, or an opt-in basis. The sampling strategy for the pilot will vary across these three scenarios. For example, if universal deployment is contemplated, then both the control and treatment groups should be chosen randomly. On the other hand, if an opt-in deployment is envisioned, then opt-in sampling would be appropriate for both groups.

These are the general principles of pilot design to ensure internal and external validity of results. As with most things in the real world, they serve as guideposts and not mandates. Utilities will need to temper these principles in actual execution given their time and resource constraints.

13.7.2. Pilot Design Approach

The very first step before designing an experiment is to determine the objective of an experiment. The objective should clearly state: (i) treatment(s) tested in the pilot; (ii) metrics that will be measured, and (iii) population about which it is intended to make inferences.

Once the objective has been clearly stated, a “sampling frame” must be developed. A sampling frame refers to a population from which a sample will be selected to participate in a pilot and expected to yield inferences about the population from which it originates. For instance, if a utility is interested in measuring the impact of dynamic prices for high-usage homes, then the sampling frame consists of the population of high usage customers.

After determining the sampling frame, the next step is to determine the "experiment design approach". Selection and implementation of a design approach have important consequences for internal and external validity of a pilot program, therefore should be decided upon by considering how a given approach would affect a pilot's internal and external validity. If a dynamic pricing program is likely to be offered on a universal basis to a population or a sub-population when it is time to offer them as a full-scale program, the most suitable design approach is a "randomized controlled trial (RCT)" approach in which participants from a sampling frame are *randomly* allocated to treatment and control groups. By ensuring that the participants are selected from the sampling frame using an approach that best approximates the participant mix of a full-scale implementation, the design approach meets the external validity requirement. By randomly allocating participants to treatment and control groups and therefore avoiding potential selection biases, the recruitment approach meets the internal validity requirement (although some additional analysis may still be needed to make sure that the control and treatment groups are comparable even with the randomization).

Pilot design should be best handled by professionals trained and experienced on the subject. Although it is not possible to give a full prescription of how to design scientifically pilots, following are the most salient pilot design principles:[158]

1. In order to measure the impact of the new rate designs (called "treatments" in the literature on social experimentation), the design should: (a) control for the effect of other factors such as weather and the economy, and (b) be capable of inferring what the customers on the treatments would have done in the absence of the treatments. Otherwise a valid cause-effect cannot be established between treatment and result.

2. This is best accomplished in two ways: (a) by including a control group in the design, comprised of customers who are similar in all other respects to customers in the treatment group, and (b) by measuring the load profiles of customers in both the control and treatment groups before the new rates (or "treatments") are initiated and during the time the treatments are initiated.

3. Sufficient numbers of customers should be recruited to fill the control and treatment groups. Too few customers in the cells will result in the inability to detect the effect of the treatment through statistical means (*i.e.*, the signal-to-noise ratio will be poor).

4. Customers should be randomly selected and assigned, to the extent practical, to the treatment and control groups. This will allow valid inferences to be drawn about the behavior of the target population.

5. Data should be collected not only on customer load profiles but also on their socio-demographic characteristics and their attitudes toward energy use.
6. Multiple treatments should be used to construct a model of customer price response (commonly called a "demand model") and to derive price elasticities. If only a single

[158] For a comprehensive discussion of pilot design principles see Faruqui, Hledik, and Sergici, "Piloting the Smart Grid," The Electricity Journal, 2009.

treatment is included, then the experiment will yield specific impact estimates for that single treatment.

7. Customers should be encouraged to stay in the pilot for as long as possible.

8. If any payments need to be made to customers to ensure that they stay through the end of the pilot, these payments should be (a) made only toward the end of the pilot, (b) unrelated to the level of their monthly usage.

13.7.3. Lessons Learned in Pilot Implementation

With pilots being implemented by many utilities over the past decade, the industry has accumulated some very valuable experiences and lessons learned in addition to the evidence for customer response to dynamic pricing. Below is a brief summary of these lessons.

Pilot Design

- The available meter footprint may not be representative of the population as a whole. If so, take this into account when drawing study samples and making inferences for population.
- Don't assume that pre-treatment data are being recorded and saved just because the meters are already in place.
- Get an early reading of the AMI data to make sure that it is recorded properly. Make sure that each hourly reading comes with at least three decimal points especially for residential customers.
- Test reasonable price differentials if the goal is load shifting. Customers are not likely to alter their behavior when the price differential is not at least 2-to-1.
- Do not test an immature technology and prices in the same experiment.
- Be prepared for delays in the deployment of the technology and/or prices due to delays in the vendor deadlines or in the back-office operations.
- Test the technology before the pilot deployment to make sure that the event signals are indeed reaching the customers
- Install enabling technologies on behalf of the customers. Never send equipment in boxes/packages which require action/time from customers. These problems will impact sample sizes and could impact internal validity.
- Set and program customers' preferences during the installation of the smart technologies and if possible, provide a detailed walk-through to the customers.
- Be aware of the challenges with having customers register for portals and IHDs.
- Be aware of the required changes to the billing system to bill for the dynamic rates. Consider ways to outsource this for experiments unless the system is already built or well underway.

Pilot Recruitment

- Do not use mass media recruitment in a controlled pilot program.
- Word of mouth can lead to "walk ins", especially in small service territories. Walk-ins must be tracked and kept separate from the research sample.
- Recruitment vendors typically use multiple channels for recruitment in pilots, including direct mail, email, web and telemarketing. These various methods often have selection issues associated with them (e.g., customers that utilities have email addresses for are not the average customer etc.). Use of multiple recruitment channels must be handled very carefully to maintain the integrity of the pilot design.
- Keep a detailed record of the recruitment process. Document how many customers were targeted, how many were contacted, how many agreed to participate.
- Recruitment for studies involving technology requires capturing key information as part of the screening and recruitment process for both treatment and control customers.
- Oversample to accommodate for potential un-enrollments. There is usually one percent un-enrollment during the pilot, other than the initial un-enrollments.
- Identify and document the reasons for un-enrollment.
- Be aware of the vulnerable customer population within your pilot sample.

Customer Management

- Provide early feedback for the savings. If it is a PTR program, let participants know how much they saved right after each event. Provide a monthly savings report for the other rate types. Consider providing saving tips.
- Set the customer expectations right. Do not over-sell the potential savings.
- Be prepared to explain bill increases with given customers' usage.
- Provide special training to the customer representatives to make sure that they are knowledgeable on the treatments that are being tested in the pilot.

Field Management

- Do not isolate recruitment vendors and implementation vendors from the impact evaluation vendors, as a thorough understanding of the process is very valuable for impact evaluation.
- Minimize the problems during the installation of the AMI meters or enabling technologies. These installation problems particularly upset some customers to the extent that they may never want to hear back from the utility.
- Test the technology during the pilot to make sure that the event signals are reaching the customers.

Communication with Stakeholders

- It is important to engage in communications with external stakeholders at the beginning of a pilot program. To the extent that there is some expected push-back to certain elements of the program, it may be possible to address these concerns before the pilot was rolled out. For instance, if there is a concern in the area about the vulnerability of low income consumers, it may be possible to address this concern by including a treatment cell in the pilot design that consists of low-income customers.

- It is also important to engage in conversations with internal stakeholders during the pilot design stage and understand the constraints of each internal division that will be asked to assist or provide input

14. DSM PLANS FOR THE LONG TERM

Several of the DSM programs considered in this study are potentially of interest for the longer term, but are not well positioned for near-term deployment. Specifically, most of these programs are not cost-effective for large scale deployment based on current market conditions. However, these programs do have significant potential for reducing the peak or overall energy use, and therefore should be re-evaluated as market conditions change or as the cost of the technology comes down. The programs are:

- Thermal energy storage
- Other forms of distributed storage
- Home electronic equipment
- Office electronic equipment efficiency
- HVAC retrocommissioning
- Process efficiency/motors

A basic description of each potential program is provided, along with a discussion of the key issues to consider when re-evaluating these programs for possible deployment in the future.[159]

14.1 THERMAL ENERGY STORAGE

The objective of a thermal energy storage program is to encourage medium- and large-sized commercial and industrial customers to install technology that will shift cooling load from peak times to off-peak times. Typically, in these programs the utility (or other implementation organization) offers a rebate to customers who purchase and install the technology. A strategic consideration could be to heavily market the program in areas of grid congestion, to defer the need for peak-related capital investment the transmission or distribution system.

Thermal energy storage is not currently cost-effective in the KSA for most customer types, because the roughly 7,500 SR/kW installation cost is roughly three times the alternative cost of building a peaking unit.[160] The price differential between peak and off-peak times, which is exploited through the energy price arbitrage capability of the technology, is much too small to overcome this cost disadvantage. Therefore, requiring thermal energy storage retrofits in existing construction, or even mandating that it be installed in new buildings, is not the most financially attractive option in most applications. Where this technology does exhibit significant potential for future cost-effective deployment is in conjunction with the development of a new district cooling system, where the investment in the cooling system could be downsized considerably as a result.

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[159] Market potential estimates are not developed for these programs, because it is difficult to establish likely acceptance rates for a program that is not cost-effective. Participation will depend largely on program incentives, to the extent that it becomes economically attractive.

[160] 2,500 SR/kW cost of peaking capacity provided by ECRA. Cost of thermal energy storage is low-end estimate based on several conversations with contractors in Saudi Arabia and the United States.

When re-evaluating opportunities for thermal energy storage in the future, the following are key questions to be considered before moving forward with implementation:

- Can the program be combined with the development of a district cooling system?
- What level of rebate would be needed to encourage customer adoption while maintaining the cost-effectiveness of the program?
- How will the customer realize the energy cost reduction benefit of the technology; does the TOU rate result in a short enough payback period?
- What fraction of commercial and industrial customers is eligible to participate? What are the size and rooftop space requirements for the technology?
- What changes in KSA power market conditions could make this program become cost-effective?

14.2 Other Distributed Storage

There is also the possibility to develop a behind-the-meter energy storage program that promotes technology other than thermal energy storage. While there are many grid-scale energy storage technologies available (such as flywheels, compressed air energy storage, or pumped hydro), the option that would be most applicable for installation at the customer's site is likely to be battery storage. Batteries can be deployed on a small scale and would therefore have the potential to apply to a wide range of sizes of customers. Some battery types are already commercially available or are approaching commercial availability. The objective of a storage program would be to promote customer adoption of these types of technologies.

Battery storage is generally not currently cost-effective as a customer application due to the very high up-front cost of the technology (roughly 11,000 to 15,000 SR/kW). However, recent studies have suggested that changing market conditions and future improvements in technology cost could lead to situations where battery storage is economic.[161] Much of the value proposition is in long-term avoided system resource investment, particularly to the extent that distributed storage can be used to address reliability issues at the distribution level. The ability of battery storage to provide ancillary services is also attractive, but that is more applicable in regions with high, volatile, and unpredictable energy prices (unlike in the current situation in the KSA).

Many of the issues to consider when re-evaluating this program are similar to those of a thermal energy storage program. Below are a few additional points for consideration:

- Battery storage can provide very fast response to rapidly changing grid conditions; if the technology is deployed on the customer side of the meter, how will this capability be capitalized upon; who will control the "dispatch" of the technology?
- Battery storage can serve as a reliable form of backup generation; which customers most value reliability and would be candidates for installing this technology at their facilities?
- Does the KSA want to play an active role in developing the market for distributed storage technologies? One possibility is to promote small deployments to demonstrate technical feasibility and to generate interest and experience with the technologies.

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161 For an example of these scenarios, see Southern California Edison, "Moving Energy Storage from Concept to Reality," March 2011.

- To what extent must the cost of the technology come down to get a point where it may be cost-effective?

14.3 HOME ELECTRONIC EQUIPMENT

Consumer electronics continue to use energy even when they are in the standby or "off" mode. Some energy is needed in this mode to provide remote controls, clocks, timers, memory, and other features. Manufacturers of these products have come to realize that this so-called phantom energy use can easily be avoided through various design changes. As such, there are a number of computer, printer, TVs and other home electronic devices which reduce the energy required to maintain these standby functions.

According to the American Council for an Energy-Efficient Economy, an estimated 45 billion kilowatt-hours (kWh) of electricity is consumed in the United States by home electronics in standby mode—or nearly 5 percent of total residential electricity use.[162] A variety of consumer electronic products in the off position use up to 50% less energy than conventional equipment. If such a program were in place in the KSA, the savings potential could be significant.

When evaluating opportunities for a home electronics EE program in the future, the following are key questions to be considered before moving forward with implementation:

- Can the program be easily adapted from other EE programs in place as a result of the short and medium-term plans?
- Are these types of products readily available for sale in the KSA?
- Do customers already generally purchase these products? If not, what level of rebate would be needed to encourage customer adoption while maintaining the cost-effectiveness of the program?
- What is the size of the market for home electronics? According to the baseline analysis (Chapter 4), home electronics make up roughly 4% of residential energy consumption. Is a 50% reduction in this amount feasible for the effort required to implement an energy efficiency program?

14.4 OFFICE ELECTRONIC EQUIPMENT EFFICIENCY

Power management features on office equipment such as photocopiers and printers provide a significant opportunity for reducing energy usage. Many of the high efficiency office equipment products feature an energy-saving mode that automatically powers them down when not in use. These features allow an energy savings of 60% or more when the equipment is not in use. On-demand fusing systems are also another major energy-saving feature of modern photocopiers and other electronic office equipment. These innovations allow the new generation of photocopiers to operate with lower heat requirements and vastly improved energy efficiency. These devices only use heat when paper is passed through the fixing mechanism the image is fixed on the paper. The new generation of copiers can make the temperature change from cool sleep mode to full operating temperature in 10 seconds or less, a vast improvement over the full minute or more required in older models. According to the Lawrence Berkeley National Laboratory, there are

[162] See http://www.aceee.org/consumer/home-electronics.

several other promising energy efficiency measures for office electronic equipment including power management controls and standby power sensors.[163]
The analysis of the baseline electric consumption characteristics for the commercial and government sectors reveals that the miscellaneous end-use (which largely covers electronic equipment) represents 6% for commercial and 17% for industrial.[164]

When evaluating opportunities for an office electronic equipment efficiency program in the future, the following are key questions to be considered before moving forward with implementation:

- Can the program be easily adapted from the existing programs in place for nonresidential customers as a result of the short and medium-term plans?
- Are these types of products readily available for sale in the KSA?
- Do customers already generally purchase these products? If not, what level of rebate would be needed to encourage customer adoption while maintaining the cost-effectiveness of the program?
- What is the size of the market for office electronic equipment? Would the potential energy savings be of a sufficient volume to justify the implementation of an energy efficiency program?

14.5 HVAC RETROCOMMISSIONING

Over time, the complex mechanical systems providing cooling to commercial and government buildings become mismatched to the loads they are serving as a result of deteriorating equipment, clogged filters, changing demands and schedules, and pressure imbalances. Retrocommissioning is a comprehensive analysis of an entire system in which an engineer assesses shortcomings in system performance, then optimizes through a process of tune-up, maintenance, and reprogramming of control or automation software. Energy efficiency programs throughout the US and Europe promote retrocommissioning as a means of greatly reducing energy consumption in existing buildings. Retrocommissioning projects commonly result in energy savings of 15% or higher.

Under a Retrocommissioning program, retrocommissioning activities would be eligible to receive incentives. The program would be designed as a customized incentive program. That is, each participant would have a unique set of measures and actions that would be designed and assessed on a custom or individualized basis. Incentives would paid on a fixed “per kWh saved” basis. Usually there are multiple retro-commissioning measures in a project which are eligible for incentives.

The program would have the following components which would be designed to accommodate the variety of customer needs and facilities in the commercial and governmental sectors:

- Custom Rebates—paid on fixed “per kWh saved” basis;

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163 See http://enduse.lbl.gov/projects/offeqpt.html.
164 See Chapter 4, Figures 4-5 and 4-6 for end-use shares for commercial and government, respectively.

- Customer referrals to qualified retrocommissioning service providers who can help customers identify appropriate and cost-effective retro-commissioning opportunities;
- More complex offerings, with the following services and requirements:
- Review design/specification and savings estimates for completeness and applicability of incentives
- Pre- and post-project inspections to estimate and verify savings
- Incentives paid on fixed $/kWh basis

When evaluating opportunities for an HVAC retrocommissioning EE program in the future, the following are key questions to be considered before moving forward with implementation:

- Can the program be easily adapted from the existing programs in place for nonresidential customers as a result of the short and medium-term plans?
- What type of technical infrastructure is currently in place in the KSA to accommodate the implementation of these programs?
- What is the size of the market for HVAC retrocommissiong? Would the potential energy savings be of a sufficient volume to justify the implementation of an energy efficiency program?

14.6 PROCESS EFFICIENCY/MOTORS

According to the baseline characteristics reported in Chapter 4, the industrial sector accounts for 22% of the electricity consumption in the KSA. Over 90% of that amount is attributable to processes and systems that are powered by electric motors. Because motors make up such a large share of the industrial electricity usage, it would be logical to at least investigate how efficient the motors and process systems that use motors are (and particularly the use of variable speed drives). While this study has identified a significant amount of cost-effective energy efficiency potential, targeting the industrial sector can oftentimes be challenging. This has much to do with the unique nature of each industrial facility and because of this uniqueness, every facility would need to be assessed for potential energy savings before any actions are taken. This process can be time consuming and expensive. A very specific type of skill set is required to make the kinds of energy assessments that will lead to efficiency improvements.

An energy efficiency program that is designed to encourage and assist industrial customers in improving the energy efficiency of their existing facilities might best be accomplished through a customized approach that allows for unique configurations of energy efficiency options that address major end uses and processes. Such a program would offer custom incentives to customers who install high-efficiency motors and other process-specific electric efficiency measures and engages equipment suppliers and contractors to promote the incentive-eligible equipment.

The program would potential have the following components which are designed to accommodate the variety of customer needs and facilities in this sector:

- Custom Rebates—paid on fixed “per kWh saved” basis; appropriate for larger and more complex projects;

- Customer referrals to qualified audit providers who can help customers identify appropriate and cost-effective retrofit opportunities;
- Provides financial incentives on projects not suitable for prescriptive incentives because of size or multiple types of equipment involved;
- More complex offerings, with the following services and requirements:
- Review design/specification and savings estimates for completeness and applicability of incentives
- Pre- and post-project inspections to estimate and verify savings
- Incentives paid on fixed SR/kWh basis

Examples of custom projects include high efficiency motors, adjustable speed drives, compressed air system improvements, production process improvements, and experimental technologies.

When evaluating opportunities for a process efficiency/motors EE program in the future, the following are key questions to be considered before moving forward with implementation:

- Can the program be easily adapted from the existing programs in place for nonresidential customers as a result of the short and medium-term plans?
- What types of technical skills are currently in place in the KSA that could accommodate the implementation of a process efficiency/motors program?
- Do industrial plants in the KSA operate at high efficiency levels despite the low cost of electricity?
- Can the Time-of-use tariff be adjusted to encourage industrial customers to self-invest in energy efficiency measures and options?
- What is the size of the market for process efficiency/motors? Would the potential energy savings be of a sufficient volume to justify the implementation of an energy efficiency program?

15. CONCLUSION

This study represents the first comprehensive DSM plan for Saudi Arabia. Developed with input from stakeholders in the KSA and industry experience from other regions of the world, it can serve as a blueprint for the activities that must happen in the future for DSM program design and implementation to be a success. The plan is a bold, major undertaking. It will require a new approach to demand-side program implementation in the KSA.

There is an urgent imperative to act quickly. This need is driven by rapid system-wide load growth, which is largely attributable to the connection of approximately a quarter million new premises in the KSA per year. There is significant opportunity to improve the energy usage of these buildings, which in some ways has fewer implementation barriers than addressing the inefficient use of energy in existing buildings.

Specifically, the plan identifies twelve key recommendations for implementing DSM. These steps are based on the five key pillars to DSM implementation: goal-setting, funding, program execution, measurement and verification, and regulatory incentives. The twelve recommendations are summarized in Table 15-1 below.

Table 15-1: DSM Program Design and Implementation Recommendations

	Recommendation	Description
1.	**Objective Statement**	Develop a statement to reflect the goals of the program. For example: *The objective of this program is to induce more efficient consumption of electricity in the KSA, with a specific focus on reductions in consumption during times of high demand. These impacts will be integrated into system planning processes to result in lower necessary grid investment.*
2.	**Targets**	The DSM programs should aim to achieve 5,100 MW and 10,200 GWh of annual system-wide peak and energy reduction by 2016, and 10,500 MW and 29,200 GWh of annual reduction by 2021. By 2021, this would equate to 37% of projected load growth and 19% of projected energy growth
3.	**Funding Approval**	Establish a set of criteria which implementing entities must meet in order to receive funding. The criteria should be consistent with the objective of proving that costs are reasonable and that benefits are likely to outweigh the costs.
4.	**Dedicated DSM Funding**	A government entity should secure public funding for DSM program implementation. Illustrative estimates suggest that the annual amounts needed could be roughly SR 5.7 billion in 2016 and 4.2 SR billion in 2021.
5.	**Energy Awareness Campaign**	Develop and implement a nationwide energy awareness campaign that (1) has a message tailored to Saudi culture based on primary market research, (2) effectively describes to customers the need for energy reduction and ways to reduce consumption, (3) utilizes all feasible media channels, and (4) includes a measurement and

		verification plan to assess program effectiveness
6.	**Rebate Payments**	Deploy a portfolio of rebate-based DSM programs. In the short-term, this would include **direct load control**, and **curtailable load management**. Aspects of **cooling efficiency** and **new building efficiency** programs would also include rebate incentives.
7.	**Energy Quota Program**	To address very short-term emergency capacity shortage situations, the KSA should consider offering an energy quota program that provides payments to customers for achieving target reductions in monthly energy usage. However, when considering an energy quota program it is important to weigh the benefits against the potentially hefty rebate costs.
8.	**Codes & Standards**	Develop standards that specify a minimum level of efficiency for **cooling** and **new buildings**. Conduct a series of public workshops or hearings on these standards, with the objectives of (1) demonstrating the value of the standards in the KSA, (2) incorporating stakeholder feedback, and most importantly, (3) identifying the organization that will be accountable for enforcing the standards.
9.	**Energy Efficiency City**	To encourage the maturation of the DSM technology market in the KSA, consider funding the development of a city that can be used to demonstrate the benefits of energy efficiency. Develop the city through partnerships with a wide range of interested stakeholders, including smart grid technology manufacturers.
10.	**Cost-based Electric Rates**	Modify the existing tariff for all customer segments to reflect the true cost of electricity. Modifications should reflect the international market price of energy and the time-varying nature of electricity costs. Rates should be piloted before being fully deployed. For short-term deployment, **interruptible tariffs** should be offered on a voluntary basis to encourage peak load reductions.
11.	**Regulatory Incentives**	Establish a mechanism for publicly financing the implementation costs of utility DSM programs. Also consider establishing a decoupling mechanism, which removes the link between the utilities' sales and revenue to eliminate disincentives to pursue DSM. Explore the attractiveness of a shareholder incentives mechanism with stakeholders.
12.	**Measurement & Verification Protocols**	The KSA should establish M&V protocols for evaluating the impacts of DSM programs and incorporating them into system planning. These protocols will represent a standardized list of reporting requirements to be followed by the organizations conducting the M&V analysis. The product of the M&V analysis should be annual reports that document the progress of the programs relative to key performance indicators (peak and energy reductions) and document lessons learned during program implementation. The KSA should also establish a load research program, which would improve future DSM planning efforts.

Key players in these activities will be MOWE, ECRA, the utilities, SEEC, and SASO. Each organization will have its own specific role and will need to be held accountable for its responsibilities in order for the execution of these activities to be a success. Additionally, in the near term it will be necessary to bring in external skills and expertise to initiate the implementation effort. Over time, these skills and knowledge base will be transferred to the Saudi organizations to create a self-sustaining approach to DSM in the KSA.

The proposed portfolio of DSM programs consists of those measures that are economically attractive with significant short-term impact potential. These are programs with high feasibility from a practical implementation perspective, given considerations about Saudi culture and the political climate. The portfolio includes direct load control, interruptible tariffs, curtailable load management, cooling efficiency, and new construction efficiency programs. The aggregate impact of these programs is summarized in Table 15-2.

Table 15-2: Summary of DSM Program Impacts

	2012	2016	2021
Energy Efficiency Program Savings (Energy GWh)			
Residential	411	7,157	19,684
Commercial	73	1,420	4,199
Government	74	1,646	5,295
TOTAL	558	10,223	29,178
Percent of Baseline Forecast	0.23%	3.29%	7.64%
Energy Efficiency Program Savings (Peak Demand MW)			
Residential	117	1,480	5,618
Commercial	12	239	709
Government	12	281	909
TOTAL	142	2,562	7,236
Percent of Baseline Forecast	0.29%	4.37%	9.67%
Load Management/Demand Response Program Savings (Peak Demand MW)			
Residential	13	159	201
Commercial	50	632	828
Government	48	545	614
Industrial	90	1,088	1,601
TOTAL	202	2,425	3,244
Percent of Baseline Forecast	0.41%	4.13%	4.34%
Budget (Annual, Million SR)			
Residential	500	3,291	2,176
Commercial	114	954	721
Government	141	1,397	1,113
Industrial	16	136	173
TOTAL	770	5,778	4,183
Carbon Savings (Tonnes)			
Residential	121,498	2,114,767	5,816,050
Commercial	21,539	419,510	1,240,552
Government	21,918	486,367	1,564,490
TOTAL	164,955	3,020,644	8,621,092

The successful implementation of the DSM programs, including incorporation of the program impacts into utility planning efforts, will result in substantial financial benefits for the KSA. Over the next decade, the programs recommended for full deployment in the short term could conservatively produce net benefits in the range of SR 3 billion. These benefits are derived from avoided investment in new generating and T&D capacity, as well as reduced energy costs at domestic prices. However, the actual benefits to the KSA could be higher than this. Specifically, it is well known that every barrel of oil sold domestically could be sold at a much higher price on the international market. To the extent that DSM programs allow for more oil to be sold internationally rather than domestically, the value of avoided energy costs is significantly higher.[165] Accounting for this, the benefits of the recommended DSM programs to the KSA could be as much as SR 50 billion. This is illustrated in Figure 15-1.

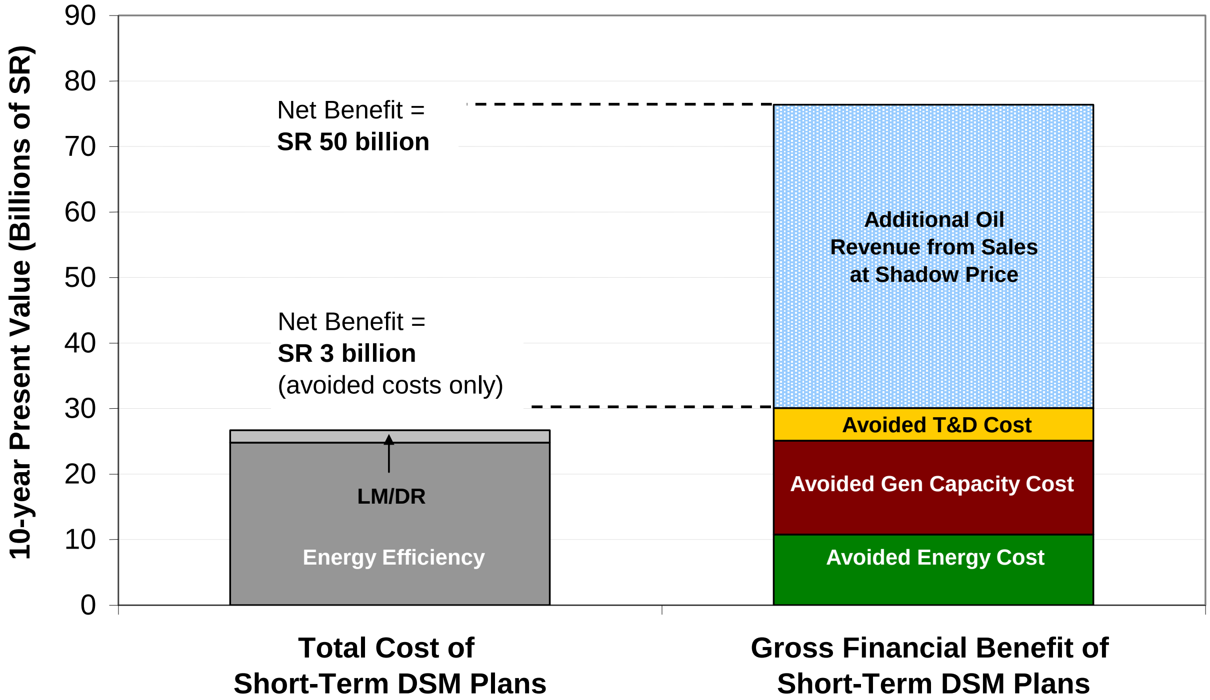

Figure 15-1: Costs and Benefits of Proposed DSM Programs in the KSA (10-year Present Value)

In addition to these financial benefits, the proposed DSM programs would also provide environmental benefits - something that could become increasingly valuable as global political pressure continues to build around reducing carbon dioxide emissions. Over the ten year lifetime of these programs, it is estimated that more than 38 billion tones of carbon emissions could be saved. By 2021, the annual reduction in carbon emissions would be approaching eight percent per year.

There would also be a direct financial benefit to SEC from these programs. Currently, even at discounted domestic oil prices, SEC is selling electricity at a rate that is below its costs. Therefore, in addition to the loss to the Saudi economy that is associated with selling oil at domestic prices, it is also the case that there is a loss to SEC associated with inefficient electricity consumption. Assuming that, on average, SEC is losing four halalas on every kilowatt-hour of electricity that it sells, the DSM programs are projected to avoid SR 2.6 billion (present value) in financial losses to the utility over the next decade.[166]

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165 Shadow price of energy is assumed to be 5.3 times higher than domestic price, based on information provided by ECRA.

166 Estimate of rate deficiency is based on informal conversations with SEC staff. Avoided financial losses are calculated by multiplying 4 hh/kWh into the annual energy savings from the DSM programs, and discounting using a 10% annual rate.

The programs presented in this report represent an opportunity for the KSA to improve system reliability, reduce unnecessary capital investment in grid infrastructure, increase national profits from international oil sales, improve overall economic efficiency, and reduce harmful environmental emissions.[167] However, this study should mark the beginning rather than the end of DSM activity in the KSA. Estimates of targets and budgets must continue to be refined and revisited as the activities progress. Particularly with respect to budgets, it is expected that the figures could move once negotiations begin with contractors and more data becomes available. Regardless, the magnitude of the estimates in this study is indicative of a substantial opportunity for improving the Saudi power sector and addressing a critical need in the nation's energy supply. In short, these programs are the key next step towards a sustainable energy future in Saudi Arabia for the coming decade.

[167] Assuming 11 hh/kWh average electricity rate. Range represents snapshots of annual budget in 2016 and 2021.

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APPENDIX A: CASE STUDY DETAILS

For each case study, we provide an overview of the key factors shaping LM/DR activity in the region. We then describe the current LM/DR regulations and policies that have been implemented in response to these driving forces. This is followed with a qualitative summary of the programs being offered in the region, as well as a quantitative assessment of the impacts of these programs, to the extent it is available.

1. CHINA

China has taken its first steps toward an effective demand response program over the past decade. Extensive market reform in the country's energy sector has concentrated increasing control over energy policy with provincial governments. In turn, these government agencies have started pilot LM/DR programs to address rapidly growing electricity demand. These LM/DR programs have realized small but immediate impacts. However, further expansion will require an improved regulatory framework and stable funding mechanisms before a more developed LM/DR portfolio can be achieved. China's current situation most closely resembles that of Saudi Arabia in many ways, with rapidly growing peak demand that is outpacing supply-side additions, frequent brownouts, limited previous experience with LM/DR programs, and a widely deployed TOU rate for large industrial customers.

Factors shaping LM/DR activity

Over the past decade, China's electricity sector has been hampered by a series of severe power shortages. In the years from 2003 to 2005, China faced significant capacity shortages, with installed capacity being between four percent and eight percent below demand at various times. These shortages were not restricted to summer peak periods, as grids in various regions had to be taken offline intermittently through the winter of 2003 and half of 2004 to reduce power consumption. At the time, a lack of operable LM/DR programs meant most problems were addressed through compulsory load shedding. This led to significant economic losses as industries were compelled to alter production and work schedules. The rapid growth of Chinese demand for electricity has increased interest in LM/DR as a means to address these emergent shortages, with first steps being taken by the national and provincial governments.

Current LM/DR regulation and policy

Energy market reform in recent years has led to significant regulatory changes which affect China's implementation of LM/DR policy. In 1997, reorganization of the Ministry of Power resulted in responsibility for approval of LM/DR being shifted to provincial governments. Most regulatory policy is thus now handled by local governments, with actual implementation of LM/DR policy requirements handled by the power companies themselves.

After the transfer of power to provincial governments, the first local regulations to directly address LM/DR were issued in 2002 in the Jiangsu province. The effort required significant governmental coordination between numerous agencies, orchestrated by a steering committee of members from the various bureaus. Extensive investigations and research on LM/DR were conducted before the first pilot programs were eventually launched.

Reform in the energy system has broken up the sector's vertically integrated structure, making it more difficult to orchestrate planning for LM/DR resources. Lack of a funding mechanism has prevented the development of widespread LM/DR policy. Previous international experience has revealed the necessity of utility and/or public funding in achieving success with demand-side programs, but uncertainty created by ongoing market reform in China has challenged the stability of emerging LM/DR funding mechanisms.

Current LM/DR programs

Time-of-use pricing: China has a national policy for offering time-of-use (TOU) pricing to specific classes of industrial customers. In one province, more than 80 percent of industrial load is enrolled in a TOU rate with a 5-to-1 peak-to-off-peak price ratio. A number of provinces have also begun offering voluntary TOU pricing to residential consumers, though with a smaller price ratio than that faced by industrial consumers. 750,000 customers have voluntarily enrolled in a TOU rate in the Jiangsu province.

Energy-storage devices: Due to the substantial proportion of power consumed by climate control units, efforts have been made in China to promote and incentivize the installation of ice-storage air conditioners and heat-storage electric boilers. Some programs have also encouraged the use of electric thermal storage for space heating. These systems make it possible for consumers to divert a significant amount of energy consumption to off-peak hours.

Interruptible power contracts: These contracts have been made available to large industrial consumers by a number of power companies. Consumers which sign them are obligated to decrease their power consumption in critical peak periods or have it interrupted, but are reimbursed through lower rates or payments for interruptions. Existing contracts typically involve a minimum curtailment of 500 kW over a duration of four to eight hours, and are active over a six month period.

Voluntary load shifting: Energy-intensive consumers in China face two separate charges; a capacity charge and an energy charge. When the capacity charge is measured in terms of maximum consumer demand as opposed to strictly transformer capacity, a consumer has an incentive to control peak energy consumption. For example, if a transformer has a 100W capacity but the consumer limits their maximum demand to 80W using a computerized control system or other means, their capacity charge would be decreased accordingly. Adjusting the calculation of this capacity charge thus incentivizes load shifting away from hours to keep maximum demand low.

Involuntary load interruption program: One province facing especially drastic shortages addressed the problem by forming an involuntary load interruption program. A coordinating group was formed by members of the local government and utilities, which worked to balance electricity demands on the basis of short-term load forecasting and power usage analysis of large industrial consumers. Based on the demand forecasting, impacted consumers were advised to execute their load shifting plan, which may involve interventions such as changing production plans, shutting down certain machines, or rescheduling employee vacations. If the consumers' plans were followed, their execution was monitored and tracked. Otherwise, the program coordinators would step in and try to resolve any difficulties. If this last step failed, power to the involved consumers was interrupted. The program targeted only industrial customers; not residential and commercial.

Electric load management center (ELMC): A number of cities have now introduced ELMCs which strive to effectively balance power supply and demand between connected locations. Shifting demand between industrial customers with varying electricity needs allows for the avoidance of serious outages. Advanced planning between local customers through the ELMC has also resulted in more efficient scheduling of maintenance and work plans.

Program impacts

Despite limited market penetration, LM/DR measures in China have achieved results in a short period of time. Most reductions have been achieved from programs which address industrial consumers, and programs that address residential consumers are uncommon. Table A-1 below depicts peak load reductions in a number of provinces for the year 2003. However, LM/DR programs were responsible for about 30% of the 10 GW total – the rest was the result of involuntary peak load shedding.

Table A-1: China's Peak Load Reductions in 2003[168]

Province	Peak load reduction (MW)
Jiangsu	2,800
Shanghai	1,700
Hubei	1,000
Hebei	250
Zhejiang	1,400
Guangdong	2,250
Hunan	700
TOTAL	**10,100**

These reductions led to large cost savings for their respective provinces. The 2,800 MW reduction in Jiangsu province saved it between $1.2 and $1.8 billion of investment in new coal plants. Of this total, 800 MW was conserved due to interruptible power contracts, which compensated participants at $0.12/kWh for interruptions. A further 500 MW was conserved through its aggressive TOU pricing program which sets peak prices at five times those of off-peak prices.

Guangdong also achieved 500 MW of its 2,250 MW reduction by implementing a three-period TOU pricing program for all industrial consumers in the county. However, in 2004 it still faced significant shortages, which it addressed by starting an involuntary load interruption program. This program led to a modest decrease in industrial peak hour consumption of 0.57%.

168 Wang, Jianhui, et al.. "Demand Response in China." *Energy* (2009). Note that the impacts in this table include involuntary load shedding.

Also of interest are the impacts of LM/DR on Beijing's load factor. Between the period from 1997 to 2003, Beijing maintained a very high load factor of 81 percent. It is estimated that, had demand-side programs not been used, the load factor would have dropped to 76.5 percent during that time. Impacts from LM/DR programs employed in Beijing include:

- 700 MW peak reduction from large industrial customers enrolled in a TOU rate,[169]
- 100 MW of peak load reduction due to interruptible load arrangements with large C&I customers such as Yanshan Petrochemical Corporation
- Adoption of electric thermal storage for space heating by more than 23,000 residential customers

2. CALIFORNIA (UNITED STATES)

California is at the leading edge of LM/DR efforts not only in the United States, but across the globe. State policy has aggressively promoted LM/DR by prioritizing it, along with energy efficiency and renewables, before all other resources for meeting the state's electricity demand. This strong push from policymakers and regulators has produced a very robust portfolio of LM/DR programs across the state, including traditional reliability-based LM/DR, dynamic pricing, and permanent load shifting.

Factors shaping LM/DR activity

Much of California's intense regulatory focus on LM/DR stemmed from the California energy crisis of 2000-2001. During this time, due to a number of factors related to the restructuring of the state's energy markets, electricity prices skyrocketed and became extremely volatile, and rolling blackouts occurred across the state. LM/DR was seen as a way to improve the competitiveness of the electricity markets, since gaming of the markets by generators was viewed as one of the major causes of these problems. These benefits, combined with a desire to address rising costs of new generating capacity and a state policy that was opposed to building any new fossil fuel-fired power plants within the state borders, caused the regulators to rethink the approach to meeting the state's electricity needs, and resulted in a renewed interest in LM/DR.

Current LM/DR regulation and policy

Regulatory activity has been the most significant driver of LM/DR activity in California. Currently, there are several policy initiatives that are shaping the path forward for LM/DR in the state.

Load management standards: LM/DR programs have been implemented in California since the 1970s. One of the first policy initiatives to formally promote LM/DR in the state was a series of load management standards developed by the California Energy Commission (CEC). These standards established three basic requirements: that the utilities produce programs designed to reduce peak demand, that these programs be cost effective relative to supply-side options, and that the programs be technologically feasible. The effort resulted in four specific statewide

[169] These customers represented 62% of total consumption.

LM/DR standards: a residential air-conditioning direct load control (DLC) program, a swimming pool filter pump control program (timer-based), a C&I audit program, and TOU pricing for all customers with demand greater than 500 kW. Recently, the CEC revisited the potential to create new standards in 2007. A proposed standard would have required that programmable communicating thermostats (PCTs) be installed in all new homes. However, customer backlash led the CEC to reconsider this proposal.

The *Energy Action Plan* (I and II): The two state energy regulators in California (the California Public Utilities Commission and the California Energy Commission) jointly have produced two energy "blueprints" for the state. The first, the *Energy Action Plan*, identified energy efficiency and demand response as top-priority resources for meeting electricity demand. Specifically, the document established a goal that five percent of the state's peak demand be met through price-responsive LM/DR over a five year period. While this target led to an increase in the level of price-based LM/DR in the state, it was not met by the utilities due to any tangible penalties or incentives for compliance. The second report written two years later, the *Energy Action Plan II*, continued to identify this as an ongoing target for price-based LM/DR in the state and reinforced the notion that LM/DR and energy efficiency should be considered the top-priority among cost-effective resources in the state.

Advanced metering infrastructure (AMI) applications: In 2008, following the successful completion of the California Statewide Pricing Pilot (which demonstrated the effectiveness of smart metering and its related programs), the CPUC approved all three investor-owned utilities' (IOUs) applications for AMI deployment. In general, the utilities found that roughly 60% of the investment cost of AMI would be offset by operational benefits, such as avoided meter reading costs.[170] The remaining cost would be more than covered by LM/DR benefits enabled by dynamic pricing – benefits such as avoided generating capacity costs and reduced energy costs. This was one of the first of such business cases that were approved in the United States and has served as a model for subsequent applications in other states.

Default dynamic pricing mandate: Consistent with the assumptions in the utility AMI applications, the CPUC has required that the utilities offer default dynamic pricing to all customers. The rate offerings are being phased in by customer class. Large and medium commercial and industrial (C&I) customers have been defaulted to critical peak pricing (CPP) rates, with the option to opt-out to TOU rates. Bill protection was offered during the first year of the rate offering, and customers will be fully exposed to the dynamic rate beginning in the summer of 2011. Small C&I customers and residential customers are being offered dynamic pricing, which is being phased in starting in 2012 as AMI continues to be deployed across the state.

Integration of LM/DR into wholesale markets: In response to a federal-level push to integrate more LM/DR into wholesale power markets, the CPUC has put a cap on the amount of reliability-based LM/DR that can be used in the state. Rather than building large portfolios of

[170] The three investor-owned utilities all filed applications with the CPUC. See, for example, SOUTHERN CALIFORNIA EDISON COMPANY'S (U 338-E) APPLICATION FOR APPROVAL OF ADVANCED METERING INFRASTRUCTURE DEPLOYMENT ACTIVITIES AND COST RECOVERY MECHANISM, filed July 31, 2007.

emergency-triggered programs, utilities are being encouraged to transition existing LM/DR programs to be price-triggered and therefore able to be bid directly into the wholesale market. This has been met with some resistance by the utilities, who feel that they are losing control over their programs and that the market is not well designed to accommodate demand-side resources, but it has been welcomed by the independent system operator (ISO).

CPUC Order on permanent load shifting (PLS): In 2006, in response to a severe heat storm that caused peak reliability problems across the state, the CPUC modified the utilities' approved LM/DR programs, asking that they dedicate a share of their LM/DR budget to programs specifically encouraging PLS adoption.[171] This led to the creation of several PLS pilots, which mostly provided a dollar-per-kilowatt discount to customers interested in installing thermal energy storage technologies. Due to significant interest in these programs over the course of the following years, in 2009 the CPUC initiated a study to explore how the programs could be most effectively expanded, and how to best incentivize greater PLS adoption. As a result of the study, it is expected that the IOUs will include an expanded portfolio of PLS programs in their 2011 LM/DR applications.

Current LM/DR programs

The portfolio of LM/DR programs offered in California generally covers the full spectrum of available LM/DR options. It includes traditional programs that have been in place since the 1970s, as well as new, cutting-edge options that are being tested through pilots and demonstration programs.

Reliability-based LM/DR: In their core offering, all of the IOUs have a portfolio of traditional, reliability-based LM/DR programs such as direct load control and penalty-based curtailment programs. These programs are dispatched during emergency events to improve grid reliability. The programs are generally considered to be the most dependable by procurement groups within the utilities, due to their established history of use, but due to the recent CPUC-mandated cap on reliability-based LM/DR, the share of these programs in the state's LM/DR portfolio is shrinking.

Price-based LM/DR: Price-based LM/DR programs being offered in California can be sub-divided into two types. One type consists of rebate programs that pay customers for peak reductions below a baseline level of usage, or down to a pre-specified usage level. These programs can have varying degrees of incentive payments and penalties for non-compliance. The other type is dynamic pricing. Currently, real-time pricing (RTP) is available to customers with peak demand greater than 500 kW and CPP is the default rate for customers with peak demand greater than 200 kW (with the option to opt-out to a TOU rate). In the next couple of years, smaller C&I customers will be defaulted to a CPP rate, and residential customers will be defaulted to a peak time rebate (PTR).

[171] PLS refers to behind-the-meter programs and technologies designed to encourage load shifting away from peak hours during all days of the year, rather than during a limited number of LM/DR events. A common form of PLS is thermal energy storage.

Aggregator programs: Aggregators are active participants in California's LM/DR efforts. Currently, they contract directly with the utilities rather than participate directly in the wholesale energy market. This is because there is no centralized wholesale capacity market in the state, so the only way for them to be compensated for the capacity value of the peak load reductions that they provide is to "sell" those reductions to the utility for the associated resource adequacy value. The utilities, then, are able to count the impacts of the aggregator programs toward their LM/DR targets.

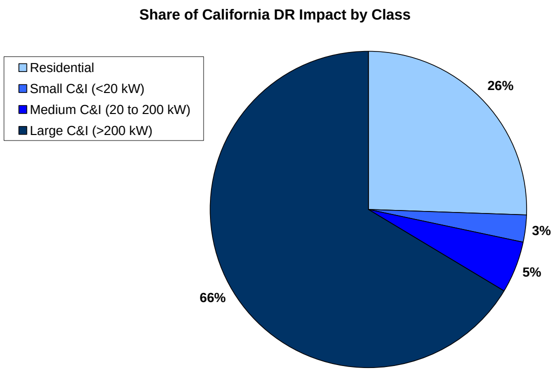
Permanent load shifting: All three of the California IOUs are running multiple pilot programs to encourage PLS. The programs provide financial incentives to adopt various thermal energy systems and are subscribed to by large C&I customers (pilot participation can range roughly from four or five large customers, to 20 or 30 customers, depending on technology and incentive level). Incentive levels can range roughly from $250/kW to $1,100/kW. The IOUs also offer TOU rates and provide technical assistance to help customers determine how to manage their operations to use less during peak periods.

Auto-LM/DR: Automated demand response (Auto-LM/DR) is the process that provides fully automated LM/DR signaling from a utility or ISO/RTO to provide connectivity to customer end-use control systems preconfigured with load LM/DR strategies. Led by the Lawrence Berkeley National Laboratory (LBNL) since 2003 through collaborative research projects funded by the California Energy Commission and other organizations, Auto-LM/DR is now seen as an important aspect of LM/DR implementation throughout the US and abroad. All three of the California IOUs offer incentives to large commercial and industrial customers to install Auto-LM/DR technologies. The incentive levels can range from $125/kW to $300/kW. Customers who are enabled with Auto-LM/DR technologies may participate in many of the LM/DR programs listed above.

Program impacts

With more than 3,300 MW of peak reduction from LM/DR, California is achieving larger megawatt impacts than any other state in the U.S. When the impact is expressed as a percentage of peak demand, California's seven percent impact ranks in the top 20th percentile (with some small states achieving larger percentage impacts through high enrollment in wholesale capacity market LM/DR programs).

Much of California's LM/DR comes from large C&I customers who are enrolled in interruptible tariffs and other types of capacity bidding programs that provide rebate payments for load curtailment during LM/DR events. There is also a significant amount of participation in air-conditioning direct load control programs among residential customers. The allocation of LM/DR impacts among customer classes and program types is shown in Figure A-1. With the current push toward price-based LM/DR and the transition to default dynamic pricing, it is expected that price-based impacts will begin to have a greater share of this total over the next several years.



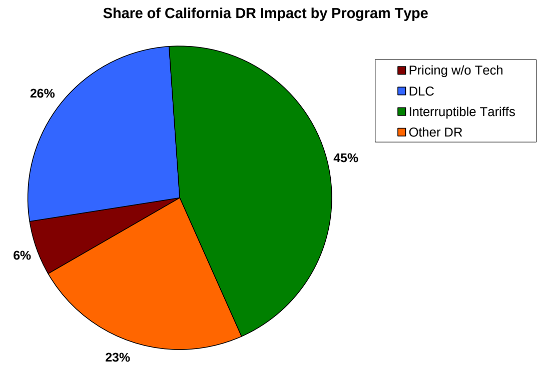


Figure A-1: California's LM/DR Impacts by Customer Class and Program Type (3,300 MW total)

Incremental to these LM/DR impacts, the utility PLS pilots are producing additional reductions in peak demand. Combined, the PLS projects have a target enrollment of over 18 MW of shifted load. Thus far, roughly 16 MW of participant load has been approved. However, only a few MW of load shifting capability has actually been installed – the remaining projects are still in the planning and installation stages.[172]

Furthermore, the Auto-LM/DR programs have led to over 100 MW of enabled loads that are capable of supplying nearly instantaneous load reductions once a LM/DR event has been called.
As the undisputed global leader in the field of LM/DR, with four decades of experience in LM/DR regulation, program design, and implementation, California's *current* approach to LM/DR provides a long term vision that is worthy of consideration by the KSA. The California experience is a good example of how, over the long term, strong regulatory direction can produce a diverse and innovative LM/DR portfolio that acts as a significant resource in a region's resource mix. As such, it is a key model for ECRA to consider as it establishes *longer-term* LM/DR goals and objectives.

3. BRAZIL

Brazil has large hydropower resources, and the availability of multi-year storage reservoirs has allowed the country to avoid problems related to capacity shortfalls in the past. However, Brazil's economy is projected to grow quickly over the next ten years, which has recently prompted the electricity system operator and government to acknowledge that the country is entering a new era where it may face capacity and transmission constraints. This has triggered interest in demand response, and especially grid modernization technologies such as smart meters and smart grid, as adjuncts to ongoing energy efficiency programs.

[172] Energy and Environmental Economics, "Statewide Joint IOU Study of Permanent Load Shifting," December 1, 2010.

Electricity supply crisis in 2001

In 2001, Brazil faced one of the most serious energy crises in the history of its power system. More than 80 percent of electricity generation in Brazil was provided by hydropower,[173] and a power sector reform initiative launched in 1998 called for the development of new gas-fired power plants to expand and diversify the country's generation capacity. While these plants were being built, the ongoing power needs would be met by drawing down the storage reservoir reserves. This strategy was undone by delays in the construction of the new power plants, the government's inability to execute long-term contracts for gas, and transmission problems at the Itaipu hydropower plant (at the time, the largest hydropower facility in the world). Despite the dwindling hydro reserves, the government did not take any firm action until a lack of rainfall in 2000 and 2001 made it clear that drastic reductions in demand would be necessary to avoid extended power outages.

Power rationing program

In June 2001, the government of Brazil created the Electric Energy Crisis Management Board (known as the GCE) to address the crisis. GCE was granted special powers to set up special tariffs, implement compulsory rationing and power outages, and bypass normal bidding procedures for the purchase of new plant and equipment. After considering a load shedding approach where each region would be subjected to power outages on a rotating basis, GCE instead developed a rate program that gave customers a two-tiered price signal. Customers were charged the standard rate for consumption up to a pre-set limit and charged a higher price for usage above the limit.

The tariff also established mandatory targets for saving energy that varied by sector. Household users that consumed less than 100 kWh per month had no savings target. All other households had a target of 20 percent savings. Commercial buildings, government buildings, and industries had targets that varied between 15 and 25 percent, while public lighting had a target of 35 percent. Customers that reduced their consumption well below the prescribed quota received bonuses, but those that did not meet the savings targets were subject to service interruption.[174] GCE conducted a large-scale awareness campaign to disseminate information about the power rationing rate and to educate customers about ways to reduce their energy consumption and increase energy efficiency.

GCE also established a market where commercial and industrial customers could engage in trading of their savings quota. A common practice was for utilities to establish an internet site where customers could post offers, and the resulting transactions would be confirmed and tracked through the utility billing and accounting system. This secondary market provided a way for high-consumption customers to exceed their quota without risk of penalty, and allowed customers that could exceed their savings target to receive additional compensation.

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173 Siddharth Suryanarayanan, Paulo Ribeiro, and M. Godoy Simoes. "Grid Modernization Efforts in the USA and Brazil – Some Common Lessons Basedon the Smart Grid Initiative." Institute of Electrical and Electronics Engineers (IEEE). 2010.

174 G. Heffner, L. Maurer, A. Sarkar, and X. Wang. "Minding the Gap: World Bank's Assistance to Power Shortage Mitigation in the Developing World." World Bank. 2009.

Results of power rationing

The power rationing program achieved extraordinary results. The program resulted in more than 20 percent reduction in monthly electricity consumption over a nine-month period in 2001 and 2002 that was needed for the crisis to pass, and load shedding and involuntary power outages were never required. A large number of customers exceeded their reduction quotas, and the government was obliged to pay out over $200 million dollars in bonuses.[175] The crisis' impact on the country's GDP was minimized because the savings quota trading market provided an important corrective mechanism to the inherent shortfalls of the quota allocation system.

Furthermore, the massive educational campaign resulted in permanent energy savings in terms of energy-efficiency equipment installations and investments. For example, a large number of households purchased and installed energy-efficient compact fluorescent lamps as part of their self-rationing strategy, thus obtaining savings over the lifetime of the equipment. Table A-2 shows the variety of energy conservation actions taken by residential customers in response to the power rationing.

Table A-2: Energy Conservation Actions Taken by Residential Customers in Brazil[176]

Action Taken by Customer	Percent of Residential Customers Taking Action
Switched off lamps	45%
Changed incandescent lamp to CFL	39%
Reduced time watching TV	31%
Ironing – less time or fewer clothes	23%
Switched off freezer	23%
Reduced time in shower	22%
Reduced use of laundry machine	14%
Switched off electric oven and microwave	14%
Reduced use of refrigerator	12%
Switched off refrigerator	12%
Shower with cold water	12%
Reduced use of electric oven and microwave	9%
Switched off stereo equipment	8%
Reduced use of stereo equipment	7%
Switched off TV	7%
Switched off laundry machine	7%
Did not use air conditioning	6%
Reduced use of freezer	6%
Reduced use of computer	6%
Switched off VCR	6%

While Brazil has not implemented programs that fit the traditional definitions of LM/DR programs, their power rationing approach to managing the 2001 supply crisis provides a good example of how innovative demand-side measures can lead to significant results.

175 Venkataraman Krishnaswamy and Gary Stuggins. "Closing the Electricity Supply-Demand Gap." World Bank. 2007.

176 G. Heffner, L. Maurer, A. Sarkar, and X. Wang. "Minding the Gap: World Bank's Assistance to Power Shortage Mitigation in the Developing World." World Bank. 2009.

4. AUSTRALIA

Australia's LM/DR activity has grown out of extensive energy market reform that started in the late 1990s. Over the past decade, significant strides have been made in encouraging evaluation of LM/DR programs as cost-effective alternatives to building generation capacity. This has led to extensive pilot programs and trials, the results of which will be useful in adopting broader policies in the years ahead. Although Australia's large coal reserves and profitable export markets are a strong force behind network expansion, regulatory authorities have developed a range of policies which encourage LM/DR in Australia's newly competitive energy markets.

Factors shaping LM/DR activity

Australia currently has some of the lowest power costs among OECD countries due to extensive large-scale coal operations. Peak demand is mainly caused by summer air conditioning, which has led to a number of pilot projects focused on curtailing load at these end uses. The limited nature of current LM/DR programs can be partially explained by a lack of incentive for retailers, as; however, the incentives for retailers to pursue LM/DR have been limited due to long-term energy contracts that do not expose them to price spikes and short-term price volatility.

Current LM/DR regulation and policy

The commencement of Australia's National Electricity Market (NEM) in 1998 marked the beginning of the competitive wholesale market that exists in the country today. Significant reform was achieved by separating the industry's generation, transmission, distribution, and retail functions into separate businesses and formalizing government oversight. In some ways, major reform minimized the appeal of LM/DR policies, as the new disaggregated businesses could not capture LM/DR benefits as easily as their vertically integrated predecessors. The new system also placed electricity retailers in a role as price risk managers for customers, who typically pay a flat rate for their energy use.

Regulatory supervision was light for the first years of this arrangement. This changed in 2002 when a broad energy market review was commissioned by the Council of Australian Governments (COAG). The report devoted significant attention to LM/DR, noting that the residential customers who are driving the country's peak demand face no price signals to influence more economically efficient energy usage. It also concluded those consumers who would otherwise offer to decrease their demand were prevented from obtaining the full value of that curtailment due to the NEM's market mechanism.

The release of this report led to a flurry of further participation by local and federal government agencies and industry groups, spurring new regulatory incentives in a number of Australian states. While local regulatory efforts have made an impact, they have had difficulty scaling up, and in 2009 six large energy systems operators were joined together to form the Australian Energy Market Operator (AEMO). As governance of Australia's energy markets becomes more consolidated, the ability to plan LM/DR measures at a national level should become more pronounced.

Despite the current lack of strong national regulation, Australia's states have taken the lead in adopting a number of innovative LM/DR policy measures. The most noteworthy of these regulatory interventions, some of which are still in development, are described below.

Victoria

Victoria's industry regulator, the Essential Services Commission (ESC), has allocated 0.6 million AUD to each electricity distributor for LM/DR initiatives. The ESC requires that each distributor provide an annual report on LM/DR measures implemented and the results. The current regulatory structure in Victoria also allows distributors to keep the difference between forecast and actual expenditures, further incentivizing any LM/DR programs which may lead to efficient distribution cost reductions.

The Victorian government has also mandated a five-year rollout of advanced metering infrastructure (AMI) to 2.3 million households. New AMI meters allow for communication between the individual consumer and an electricity retailer's systems. On the consumer side, this allows for installation of in-home display units to provide data on the level and price of their current consumption, as well as customer-controlled load management devices which can regulate the energy usage of major household appliances. On the distributor's side, these meters allow for enhanced load management functionality including direct load control, which can be used to shift non-essential load out of peak periods.

New South Wales

New South Wales requires its distributors to publish annual Electricity System Development Reviews, which report on foreseeable constraints in electricity supply. Before further investment can be made in generation, the state's *Demand Management Code of Practice* explicitly orders a full investigation of the cost-effectiveness of DSM alternatives.

New South Wales also employs an innovative scheme to remove the disincentives towards LM/DR created by the weighted average price cap which is commonplace in Australia. The use of this cap effectively encourages distributors to meet large demand forecasts in order to reach their required revenue allowance. In order to counteract this, the state regulator introduced a mechanism known as the D-factor. The D-factor is introduced to the price cap control formula and allows distributors to recover approved LM/DR implementation costs, as well as the revenue foregone as a result of any LM/DR activities. Specific methodologies for the calculation of these costs were published and are currently being considered by other state regulators.

South Australia

South Australia has attempted to encourage trial projects of multiple LM/DR mechanisms through a 20.4 million AUD investment through ETSA Utilities, the state's electricity distributor. The funding is provided by the Essential Services Commission of South Australia (ESCOSA), the state's regulatory authority. This funding is earmarked for LM/DR initiatives categorized according to the following list.

- Power factor correction
- Direct load control
- Voluntary and Curtailable load control
- Demand management organization within ETSA Utilities
- Standby generation
- Critical Peak Pricing
- Aggregation

Figure A-2: Approved categories of LM/DR initiatives for ESCOSA funding[177]

ESCOSA intends the funding to mostly support pilot programs, which are evaluated on cost, customer participation, and resulting reductions in peak demand. Despite the significant investment, the resulting pilot programs are not expected to alter investments in further electricity generation in the short term, and the funding supplied by ESCOSA does not impact ETSA Utilities' allowed expenditures for network expansion.

Current LM/DR programs

Time-of-use pricing: A number of innovative time-varying pricing measures have been implemented by Australian electricity companies. Referred to in Australia as dynamic peak pricing (DPP), these programs charge usage at a higher rate during peak periods of which the customer is notified only shortly before they begin. Trials have been conducted using in-home display units and interval meters which allow for accurate reporting to consumers of up-to-the-minute energy consumption and rates. A number of tiered seasonal rates are set, including critical peak events which can be called a maximum of 12 times per year. In one program run by Country Energy, customers are alerted of an upcoming critical peak period with a minimum of only 2 hours notice.

Another experimental program by EnergyAustralia sets a "shock price" for critical peak periods at 23 times the standard rate, one of the highest peak pricing multiples used worldwide. This price can be invoked a maximum of 12 times per year, for a maximum of four hours each time. To offset the extreme price increase during critical peak periods, the program allows for off-peak and shoulder rates which are usually 20% lower than standard rates.

Interruptible power contracts: Contracts which allow power companies to decrease power supply to large industrial consumers during peak periods exist in Australia, but arrangements are typically site specific and confidential. Despite their specific nature these contracts can help defer significant investments in increased generation. One such agreement between Integral Energy and a large industrial customer with 12 MVA of demand allowed integral to defer a 1.7 million AUD generation investment. The agreement provides the customer with 24 hours notice of the upcoming load shift, which the customer accommodates by speeding up production before the peak begins and decreasing production during the peak period.

Direct load control: The use of direct load control is still in its early stages. However, a number of trials and pilot projects have been run with positive results. ETSA Utilities took advantage of AMI infrastructure to regulate air conditioner usage and address peak periods caused by

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[177] Essential Services Commission of South Africa. "ETSA Utilities Demand Management Program Progress Report." (2008)

summertime climate control. Using a radio controlled system, ETSA interrupted air conditioners for 7.5 minutes in every 15 minutes or for 15 minutes in every 30, leading to large load reductions in early evening peak periods.

A program to remotely control electricity usage in commercial buildings in Sydney has also been tested. By linking individual building energy systems to a central control point, EnergyAustralia was able to remotely decrease load for up to six hours during peak periods. Required decreases in energy demand were allocated across all participating buildings, so that each contributed to any needed demand reductions.

Program impacts

Regulatory efforts to encourage implementation of cost-effective LM/DR measures have led to deferrals of network investments by a number of energy distributors. Measures which target residential consumers have proved especially successful. This is especially encouraging in the Australian market, where peak demand is largely created by residential air conditioning use. For this reason, the largest amount of experimentation has occurred with DPP pricing measures. These interventions have had the most success in shifting residential demand.

The use of LM/DR measures is beginning to grow in Australia, but many programs still exist as pilot projects or trials, and the next challenge will be further expansion. Significant progress has been made towards improving the regulatory environment for LM/DR, and increasing investment in LM/DR measures suggests broader expansion may be nearing. The consolidation of industry and government entities under the AEMO may come to act as an organizing force in facilitating this process.

5. SOUTH KOREA

The Republic of Korea (South Korea) views demand response as an important resource that can help solve capacity shortfall issues. Although not at the leading edge of demand response efforts, the country has gained experience in LM/DR program implementation during the past ten years. Going forward, the country aims to make significant advances in LM/DR technology development (especially Smart Grid) and become one of the global leaders in the field.

South Korea first introduced time-of-use tariffs in the 1970's, and continued to add other load management activities during the 1980's and 1990's. However, the country did not implement programs that fit the definition of modern demand response until the beginning of the past decade. South Korea's recent history of demand response implementation provides useful information and lessons learned that can be applicable to Saudi Arabia's first efforts in this area.

Factors shaping LM/DR activity

In 2010, South Korea's electricity consumption and peak demand were expected to increase by 7 percent and 11.8 percent respectively relative to the previous year. This surge in consumption and peak demand represents a continuation of recent trends that is fueled by strong economic growth and hot summer temperatures in the country. The government's Ministry of Knowledge

Economy forecasted that the electric demand would reach 70 GW during the peak summer hours in 2010. In comparison, South Korea's new generating capacity has been increasing at only 3.7 percent annually and amounted to a total of 75 GW in 2010.[178] This means that electric power reserves could fall to 5 GW (7%) or less during peak times on hot days. South Korean officials are concerned about the relatively small reserve margin because there is a substantial risk of power outages should the country experience a severe heat wave or generator failures.

The declining reserve generation capacity is an issue that South Korea has faced throughout the past decade, and it has been brought to the forefront recently by the increase in concerns over erratic weather patterns due to climate change and the environmental effects of peak electricity production by fossil fuel-based generators. As such, South Korea has been placing more emphasis on demand response and load management activities compared to energy efficiency.

Current LM/DR regulation and policy

Currently, there are several policy initiatives that are shaping the path forward for LM/DR in South Korea.

Revision of the Electricity Industry Law: In June of 2001, the Electricity Industry Law was revised to implement two major changes. Before the revision, all demand side management (DSM) programs including load management and energy efficiency were managed and implemented by the Korea Electric Power Company (KEPCO). KEPCO was South Korea's only electric utility provider, and its management of the DSM programs was perceived to be inefficient and lacking innovation. The revised law transferred the management of DSM programs from KEPCO to the government Ministry of Knowledge Economy in order to provide better vision and direction of the programs. Secondly, the revised law established the Electricity Industry Infrastructure Fund by placing a tariff on ratepayers' electricity bills. The Ministry of Knowledge Economy is responsible for allocating budgets from the Fund to KEPCO for DSM program implementation. In 2006, the Ministry announced the 3rd National Electricity Demand Forecast and Supply Plan in which the budget for DSM implementation was significantly increased. Then in 2008, the Ministry presented a roadmap for developing demand response activities and effectively placing demand response into the spotlight as the most effective solution for solving the country's reserve capacity issues.

Dependency on imported fuels and response to climate change: Peaking generation plants in South Korea mainly use imported LNG and oil as source of energy. Using demand response as a capacity resource would allow the country to decrease the construction of new peaking plants and dependency on imported fuels. In November 2009, the Presidential Committee on Green Growth announced the national goal of cutting the country's greenhouse gas emissions by 30 percent compared to the business-as-usual baseline by 2020 in order to participate in the ongoing global efforts to mitigate climate change.[179] In this way, South Korean officials view demand response as a way to reduce consumption of imported fuels and increase energy security, and at the same time to help achieve the country's greenhouse gas reduction goals.

178 "Korea Power Exchange Leads Upgrading Smart Grid System." The Korea Post. August 2010.
179 "National Roadmap for Smart Grid." Presentation by the Ministry of Knowledge Economy. January 2010.

Creation of a new growth engine: The South Korean government has recognized the importance of the development of demand response technologies as a new growth engine for the country's economy. In particular, the Ministry of Knowledge Economy has targeted the smart grid as the key to expanding the markets for renewable energy, electric vehicles, as well as demand response. In 2009, the Ministry announced a National Roadmap for Smart Grid which includes plans to spend $24 billion U.S. dollars through 2030 to finance the country's smart grid initiative.[180] As part of this effort, the Korea Electrotechnology Research Institute (KERI) is engaged in a major Smart Grid R&D initiative that is focused on smart grid technology research and electricity industry policy research covering demonstration of real-time demand response solutions, including pilot programs targeting large commercial and industrial customers.[181] In addition to building a smart grid at home, South Korea also plans to become a major provider of the knowledge and technology in the global market and thus turn smart grid into a major export industry.

Current LM/DR programs

The portfolio of LM/DR programs offered in South Korea covers both price-based and incentive-based LM/DR options.

Price-based LM/DR: KEPCO first introduced a seasonal tariff program and a TOU tariff program during the 1970's to reduce customers' electricity demand and to improve the system load factor. Today, the TOU tariff is the only price-based program in place.

Incentive-based LM/DR: KEPCO currently offers a portfolio of incentive-based LM/DR programs. The individual programs are briefly described below:

- Demand Adjustment Program of Advance Notice: financial incentives are offered to customers (with peak demand of 300 kW or greater) who reduce their demand during peak hours in 15 peak days. The load reduction amount is specified in the customer's participation agreement with KEPCO. The peak days occur during the July 1 to August 31 window, and are announced by KEPCO in advance each year.
- Demand Adjustment Program of Designated Period: financial incentives are offered to customers (with peak demand of 300 kW or greater) who reduce their demand during peak hours in a number of peak days. The load reduction amount is specified in the customer's participation agreement with KEPCO. The peak days occur during the July 1 to August 31 and December 1 to January 31 windows, and are announced by KEPCO one week in advance.
- Chiller and Heater Remote Controlled System: financial incentives are offered to customers (with chiller demand of 40 kW or greater) who install a remote controlled system that allows KEPCO to cycle the equipment during situations involving low supply margins.
- Average Load Reduction Upon Request: financial incentives are offered to customers (with peak demand of 300 kW or greater) who reduce their demand upon request. The

[180] "Korea Power Exchange Leads Upgrading Smart Grid System." The Korea Post. August 2010.
[181] "Development of Policy/System Options on Real Time Demand Response, 2nd year achievement and 3rd year plan." Presentation by the Korea Electrotechnology Research Institute. September 2010.

load reduction amount is specified in the customer's participation agreement with KEPCO. KEPCO's request for load reduction are announced at least 3 hours prior and only during emergency situations.

- Direct Load Interruption: financial incentives are offered to customers (with peak demand of 300 kW or greater) who allow KEPCO to interrupt electric service during emergency situations involving low supply margins. The incentive payment varies according to the period of advance notice (more incentives are paid for a short period of event announcement, e.g. notification within 3 hours of service interruption).

Permanent load shifting (PLS): KEPCO currently offers two PLS programs, and both involve thermal energy storage. The Cool Storage System program offers subsidies and loans to customers that install a chilled water or ice storage system in their commercial buildings. The Ice Storage Air-Conditioners program offers the same subsidies and loans to residential customers that install an ice storage system in their homes.

Program impacts

According to KEPCO, their LM/DR programs achieved a peak reduction of 2,683 MW in 2006. This figure does not include any load reduction due to direct load control or emergency LM/DR programs, since KEPCO never called curtailment events for these programs during that year. This level of load reduction represents approximately 4.5 percent of the peak demand in 2006.[182] Program impact information for more recent years is unavailable at the time of this writing.

6. ITALY

Italy, with 30 million smart meters already installed, leads European countries with respect to advanced metering penetration. Additionally, regulators have instituted a mandatory Time of Use rate, which is currently being phased in for all customers. However, with these exceptions, Italy's demand response programs are otherwise still in relatively early stages. The primary demand response programs in the country are traditional interruptible programs and load shedding programs. More innovative demand response programs, such as mass market direct load control and Critical Peak Pricing, are being considered as possibilities for the future.

Factors shaping LM/DR activity

Italy initially turned to energy efficiency programs and renewable generation during the oil shocks of the 1970s and 1980s. In recent years, the issue of global warming has again refocused attention on demand-side measures. Historically, Italy's only LM/DR programs were Interruptible Programs for large industrial customers, developed in the late 1970s due to generation capacity shortages.

Today, regulators and utilities are turning to demand response to help reduce the marginal cost of generation and keep prices in check. Italy relies heavily on imported fuel, and more than half of domestic electricity production comes from natural gas. Italy's dependence on oil for producing

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[182] Jin-Ho Kim, Tae-Kyung Hahn, and Kwang-Seok Yang. "Roadmap for Demand Response in the Korean Electricity Market." Institute of Electrical and Electronics Engineers (IEEE). 2009.

electricity is much higher than that of other European countries, and therefore Italian customers' power bills fluctuate significantly with changes in the price of oil. As a result of these factors, Italy has had some of the highest electricity retail prices in all of Europe.

Current LM/DR regulation and policy

As a member state of the European Union, Italy is subject to the directives of the EU Parliament. The Energy Services Directive requires member states to develop plans for reducing energy consumption, which may include demand response programs such as TOU rates. The Energy End-Use Efficiency and Energy Services Directive calls for member states to promote real time demand management technologies such as smart meters. Another directive calls for the customers to be provided with information on their own consumption often enough to regulate their own consumption.

Beyond these guiding directives, Italy had the autonomy to design its own electricity market and regulatory framework. The Italian Regulatory Authority for Electricity and Gas (or "L'Autorità per l'energia elettrica e il gas" - AEEG) regulates the electricity and gas sectors, including price and tariff regulation. Importantly, the AEEG has encouraged smart meter deployment through Resolution 39/10, which provides incentives to support smart grid development and smart meter installation. As of mid-2009, Italy had roughly 30 million smart meters installed and working (roughly 90 percent of all meters), a far higher percentage than any other European country.[183] Full deployment is expected in the next few years. The AEEG has also initiated mandatory TOU pricing, as discussed in the next section.

Current LM/DR programs

TOU Pricing: Mandatory TOU pricing is being rolled out to all customers with smart meters. As of December 2010, 20 million customers were on the TOU rate, and by the end of 2011, all household customers (roughly 24 million) will be enrolled. The rate is designed such that a customer who consumes less than 1/3 of his total consumption in the peak hours will see a bill decrease. The peak period is 8 AM to 7 PM on working days. In response to requests from consumers' associations, the AEEG has instituted an 18-month transitional period, during which there is only a 10 percent difference between the peak price and the off-peak price. The AEEG hopes that this period will allow customers to become accustomed to the rate structure while protecting them from large bill changes.

Interruptible Programs: Participants of interruptible programs are required to reduce their load to specified levels during interruption events, or face financial penalties. The participants are all large industrial customers. The compensation for participating in the program in 2007 was roughly $190,000/MW-yr (US dollars) for up to 10 interruptions per summer, plus an additional $3,600/MW-yr for any additional interruptions.

[183] Enel SpA, Italy's dominant utility, deployed smart meters to its entire customer base between 2000 and 2005. This was the largest smart meter deployment in the world. Today, the utility claims that 32 million of its customers are managed remotely via the smart meter.

Load Shedding Programs: Italy's load shedding programs allow the utility to remotely shut down a participant's power. Participants must install Load Shedding Peripheral Units to participate in the program, and utilities can remotely shut down participant's equipment through this device, either at no notice (i.e., real time) or with 15-minute notice. Utilities can curtail 10 MW of power for programs without notice and 3 MW of power for programs with notice.

Program impacts

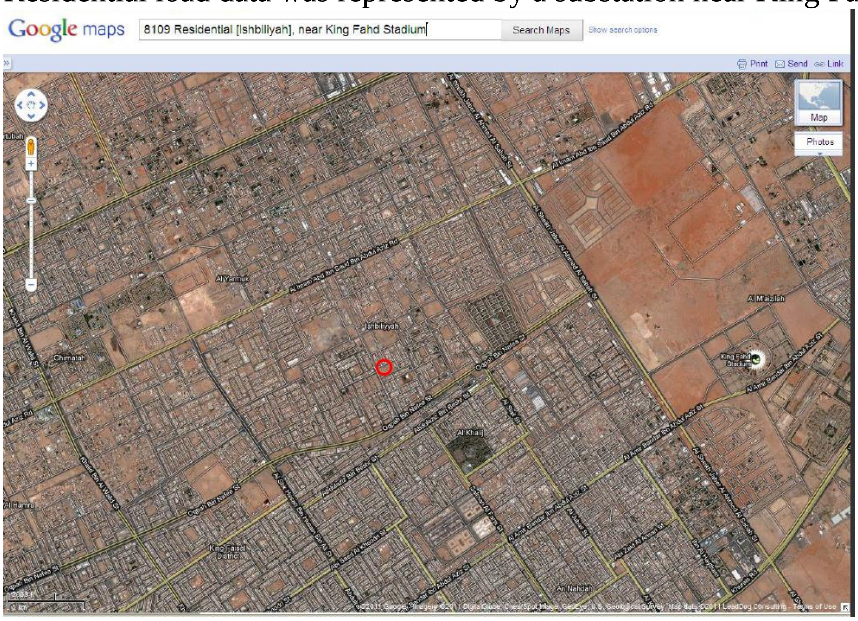
The TOU program impacts are still in the process of being measured, with a panel of customers being monitored for 18 months between July 2010 and December 2011. The AEEG estimates that if households shift 10 percent of consumption to off-peak hours, carbon emissions will be reduced by 450,000 tons per year, equivalent to the emissions of a power plant serving a city of 500,000 residents. Financially, this estimate corresponds to 9 million Euros per year for reduced carbon emissions, 80 million Euros in fuel costs, and more than 120 million in plant costs. Overall, the AEEG expects the TOU rate to save more than 200 million Euros per year.

There is little evidence available for the impacts of other current LM/DR programs at this time.

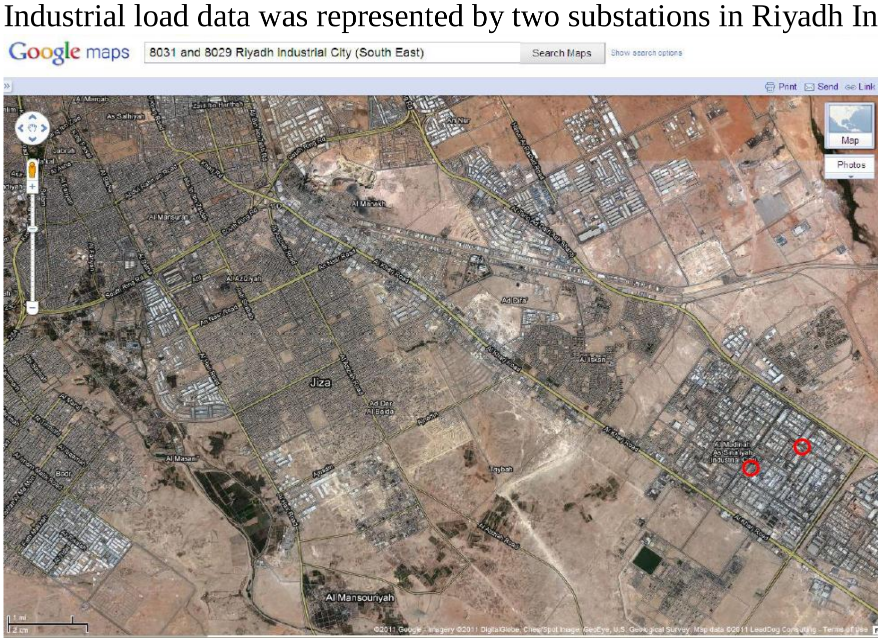
APPENDIX B: CUSTOMER SEGMENT LOAD SHAPES

This appendix provides additional detail on the development of the daily customer segment load shapes that are illustrated in Chapter 4. The data was collected from substations that were mostly located in or around Riyadh. Data from multiple substations was collected for each segment. Below are examples of substations that were used in this analysis.

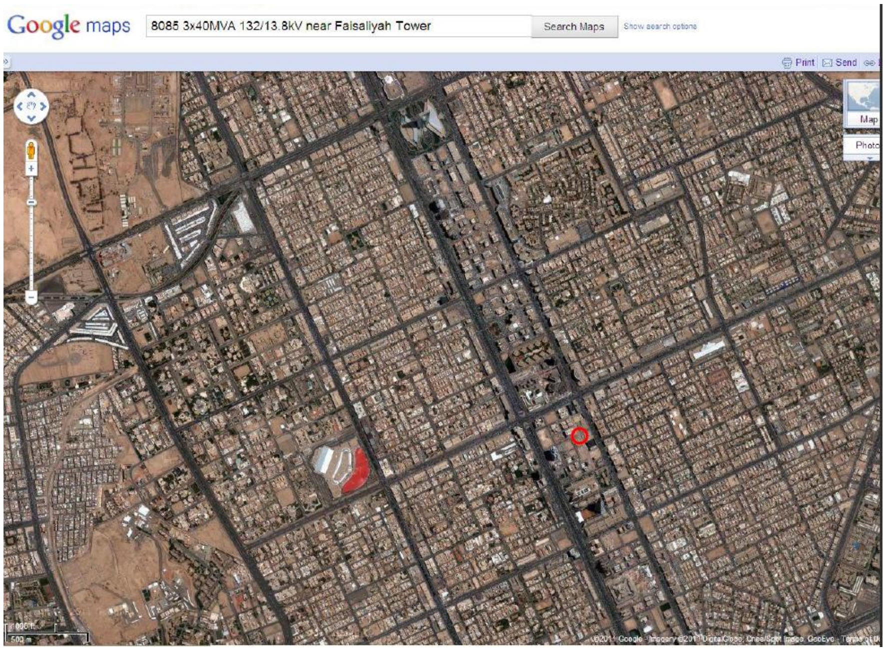
Residential load data was represented by a substation near King Fahd Stadium:



Industrial load data was represented by two substations in Riyadh Industrial City:



Commercial load data was represented by a substation near Faisaliyah Tower:



In addition to these substations, data was collected for the Faisaliyah complex, an area near Anoud tower, and an area west of the new financial district.

There were several issues associated with the substation load data that required some cleanup and modification. Three steps in developing the load curves are listed here and detailed below:

1. Import and clean the data
2. Match demand readings to integer hours
3. Normalization and graphing

First the data for each substation was compiled into a single file, and then read into the programming language called "R." Each record represented the demand for one time interval of a particular day. Rows where demand was listed as "Bad" or "Not Connected" were dropped.

After cleaning the data, the demand readings needed to be matched with the closest integer hour (i.e. a reading at 12:03 PM should be kept as the reading at the hour beginning 12:00 PM). In this process, if a substation had no reading between the half hour preceding or following a certain hour, it was dropped. For example, if there was no reading between 3:30 AM and 4:30 AM, 4 AM would have no reading for that day and be dropped. If there were two readings near an integer, the closest was kept. One example would be if there were readings at 3:05 PM and 3:13 PM, then the 3:05 PM reading would be recorded as the 3 PM demand for that day.

Once the hourly dataset was established, the average weekday load profiles were calculated. Each hour in the load profile represents the average of all the weekdays with a reading for that hour. Most substations had data beginning July 1, 2010 through August 31, 2010. Others only had legitimate data for the month of July. To normalize the demands for each substation, every demand reading was divided by the highest demand for that substation in the available data. The result is the summer load profiles illustrated in Chapter 4.

APPENDIX C: ADDITIONAL DETAIL ON LM/DR FEASIBILITY ANALYSIS

Chapter 5 presented an analysis of the system load curve to determine the feasible impact of LM/DR in the KSA, with the year 2009 as the example. The same analysis has been conducted for other years in which load data was available (2007 through 2010). Figure C-1 below illustrates the top 200 load hours for each of those years. Note the consistent growth in peak demand from year to year.

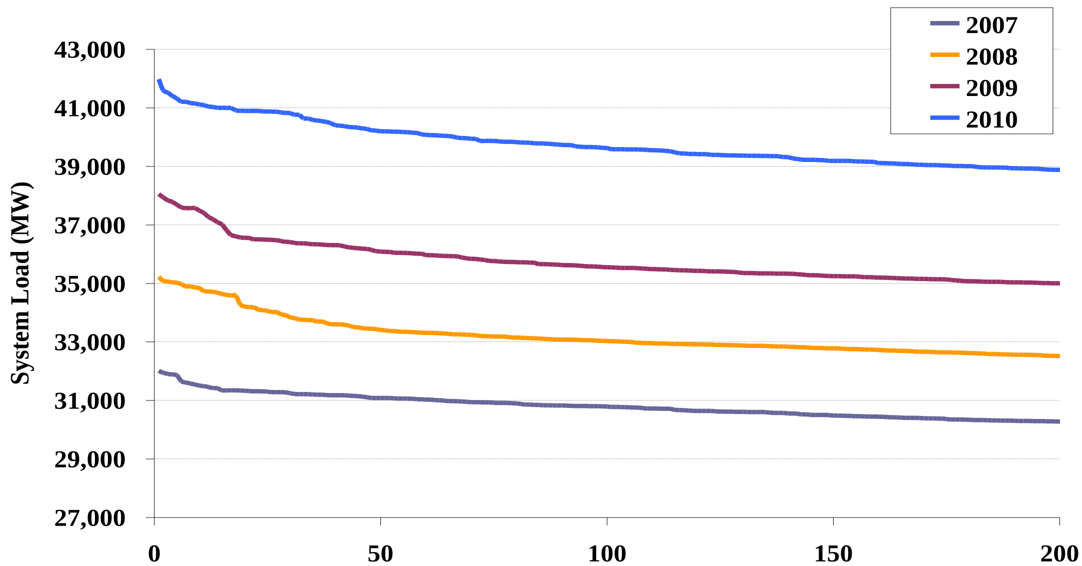


Figure C-1: SEC System Load Duration Curve (Top 200 Hours)

The annual variation in load patterns shown in Figure C-1 can lead to differences in the results of the feasibility analysis from one year to the next. The detailed results of this analysis are presented for each year from 2007 through 2010 in Table C-1 below.

Table C-1: LM/DR Feasibility Analysis (2007 - 2010)

Critical Period	Total	Range
2007		
Hours	165	10 am to 4 pm
Days	45	Every day except Friday
Months	4	June, July, August, September
2008		
Hours	46	11 am to 4 pm
Days	17	Every day except Friday
Months	4	June, July, August, September
2009		
Hours	47	Noon to 4 pm
Days	22	Every day except Friday
Months	3	June, August, September
2010		
Hours	71	Noon to 5 pm
Days	27	Every day of the week
Months	4	June, July, August, September

With the exception of year 2007, which appears to be an anomaly in the available data, critical hours are contained within the window of time between 11 am and 5 pm. Most of those hours fall between noon and 4 pm. June through September are consistently the important months across all years being analyzed. Critical hours tend to fall on any day except for Friday, although in 2010 there were critical hours on Friday as well. 20 to 25 LM/DR events would have produce close to a five percent reduction in peak demand in any year except for 2007.

APPENDIX D: LOAD CURTAILMENT ACTIONS TAKEN BY CUSTOMERS

There are many means by which customers can reduce their electricity consumption during LM/DR events or higher-priced peak periods. Recently, experiments have measured changes in customer consumption patterns as a result of being enrolled in time-varying rates. As part of these experiments, participants were asked what actions they took to reduce consumption. Figure D-1 lists the responses from the California Statewide Pricing Pilot.

Residential
Shift laundry
Use appliances less
Turn off lights
Turn AC off/use less
Shift dishwasher use
Reduce laundry water temperature
Shift pool/spa pump/filter use
Improvements to home EE
Turn up AC temperature
Turn off appliances
Turn off tv/computer
Do not use stove/oven
Leave house
Shift cooking time
Reduce fan usage
Line dry clothes
Use "Heat off" setting on dishwasher

Business
Turn lights/equip off when not needed
Turn AC off more
Raise thermostat setting on AC
Replace lights/fixtures with more efficient
Install programmable thermostat
Change hours of operation
Remove lights/reduced wattage
Install lights/equipment timers
Make improvements to facility EE
Shift employee work schedule
Chang hours of operation
Replace old equipment

Source: Compiled from several reports on end-of-pilot surveys conducted during the California Statewide Pricing Pilot.

Figure D-1: Load Curtailment Actions Identified in the California Statewide Pricing Pilot

Figure D-2 shows the percent of participants who took a particular action during the 2009 Baltimore Gas & Electric Smart Energy Pricing Pilot.

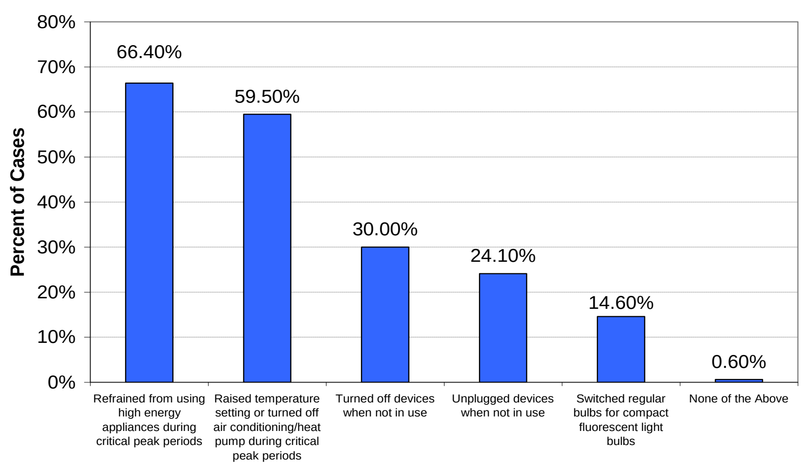


Figure D-2: Customer Behavior in the 2009 Smart Energy Pricing Pilot[184]

[184] Source: 2009 Smart Energy Pricing (SEP) Post Pilot Program: Residential Customer Experience Comparison Report, Maryland Marketing Source

APPENDIX E: DETAILED DESCRIPTIONS OF EE MEASURES

This appendix presents detailed information for all energy efficient measures that were evaluated for this study. Four tables are provided:

- Table E-1 provides brief descriptions for all measures for the residential sector.
- Table E-2 provides brief descriptions for all measures for the commercial sector.
- Table E-3 provides brief descriptions for all measures for the government sector.
- Table E-4 provides brief descriptions for all measures for the industrial sector.

Table E-1: Residential Energy-Efficiency Measure Descriptions[185]

End-Use	Measure	Description
Cooling	Central Air Conditioner – High Efficiency	Central air conditioners consist of a refrigeration system using a direct expansion cycle. Equipment includes a compressor, an air-cooled condenser (located outdoors), an expansion valve, and an evaporator coil. A supply fan is located near the evaporator coil in order to distribute supply air through air ducts to many rooms inside the building. Cooling efficiencies vary based on the quality of the materials used, the size of equipment, the condenser type and the configuration of the system. Central air conditioners have all of their components housed in a factory-built assembly. The US-based Energy Star Program rates the energy efficiency of central air conditioners according to the size of the unit. A metric of efficiency performance is the Energy Efficiency Rating (EER). The EER values used for this study are as follows: baseline=7.96; high efficiency=10.6. These values were based on information collected during limited field visits while in the KSA over the course of this study. Cost data are based on estimates from US sources, with appropriate modifications to represent cost conditions in the KSA.
Cooling	Split Air Conditioner – High Efficiency	Split system air conditioners operate in the same manner as central air conditioners above. These systems however have an outdoor condenser section and an indoor evaporator section connected by refrigerant lines and with the compressor at either the outdoor or indoor location. The EER ratings typically follow the same ranges that are found with central air conditioners. Thus, the EER values used for this study are as follows: baseline=7.96; high efficiency=10.6. These values were based on information collected during limited field visits while in the KSA over the course of this study. Cost data are based on estimates from US sources, with appropriate modifications to represent cost conditions in the KSA.
Cooling	Air Conditioner - Room, Energy Star or better	Room air conditioners are designed to cool a single room or space. This type of unit incorporates a complete air-cooled refrigeration and air-handling system in an individual package. Cooled air is discharged in response to thermostatic controls to meet room requirements. Each unit has a self-contained, air-cooled direct expansion (DX) cooling system and associated controls. Room air conditioners come in several forms, including window, split-type, and packaged terminal units. The US-based Energy Star Program rates the energy efficiency of room air conditioners according to the size of the unit. Energy Efficiency Ratings (EER) typically range from 8.2 to 10.2, or greater. The EER values used for this study are as follows: baseline=7.96; high efficiency=10.6. These values were based on information collected during limited field visits while in the KSA over the course of this study. Cost data are based on estimates from US sources, with appropriate modifications to represent cost conditions in the KSA.
Cooling	Programmable Thermostat	A programmable thermostat can be added to most cooling systems. They are typically used during the summer to increase temperatures during the afternoon. There are two-setting models, and well as models that allow separate programming for each day of the week. The energy savings from this type of thermostat are identical to those of a "setback" strategy with standard thermostats, but the convenience of a programmable thermostat makes it a much more attractive option. In our analysis, the baseline is assumed to have no thermostat setback.
Building Shell	Insulation, Ceiling	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. Typical insulating materials include: loose-fill (blown) cellulose; loose-fill (blown) fiberglass; and rigid polystyrene.

[185] Note that all EER values quoted in the tables are at 35 degrees C and not 45 degrees C as sometimes used in the KSA. Note also that an improvement in EER has a direct proportional relationship to energy savings (e.g., a change in EER from 8.0 to 10.0 gives a 25% improvement in energy consumption).

Table E-1: Residential Energy-Efficiency Measure Descriptions[185]

End-Use	Measure	Description
Building Shell	Insulation, Wall Cavity	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. For the KSA, the typical building stock is block construction which makes traditional inside the wall insulation measures such as batt insulation options impossible to implement. As such, we assumed exterior shell treatments that yield comparable R-values (e.g., the measure of thermal resistance) to the traditional measures described above.
Building Shell	Windows, High Efficiency	High-efficiency windows, such as those labeled under the Energy Star Program, are designed to reduce a building's energy bill while increasing comfort for the occupants at the same time. High-efficiency windows have reducing properties that reduce the amount of heat transfer through the glazing surface. For example, some windows have a low-E coating, which is a thin film of metallic oxide coating on the glass surface that allows passage of short-wave solar energy through glass and prevents long-wave energy from escaping. Another example is double-pane glass that reduces conductive and convective heat transfer. There are also double-pane glasses that are gas-filled (usually argon) to further increase the insulating properties of the window.
Building Shell	Windows, Shading	Physical features on the exterior of buildings that provide additional shade for windows and/or wall areas. This reduces the heat gain of the building from direct sunlight, which reduces the cooling load, thus saving cooling energy.
Lighting	Compact Fluorescent Lamps	Compact fluorescent lamps can consist of either electronic or magnetic ballast and a twin tube or quad tube lamp. They are designed to be a replacement for standard incandescent lamps and use about 25% of the energy used by incandescent lamps to produce the same lumen output. Integral compact fluorescent lamps have the ballast integrated into the base of the lamp and have a standard screw-in base and a spiral design which permits installation into existing incandescent fixtures.
Lighting	Fluorescent, T8 Lamps and Electronic Ballasts	T8 fluorescent lamps are smaller in diameter than standard T12 lamps, which result in greater light output per watt input (more efficient lighting). T8 lamps also operate at a lower current and wattage, which also increases the efficiency of the ballast but requires the lamps to be compatible with the ballast. Fluorescent lamp fixtures can include a reflector that increases the light output from the fixture, and thus making it possible to use a fewer number of lamps in each fixture. T5 lamps further increase efficiency by reducing the lamp diameter. Based on limited field observations in the KSA for this project, there might be a significant number of T10 lamp configurations as well.
Lighting	LED Lamps	LED lighting has seen recent penetration in specific applications such as traffic lights and exit signs. With the potential for extremely high conversion efficiency, LED's show promise to provide general use white lighting for interior spaces. Current models commercially available have efficacies comparable to CFL's. However, theoretical efficiencies are significantly higher. White LED models under development are expected to provide efficacies greater than 80 lumens per watt.
Water Heating	Pipe – Hot Water, Insulation	Insulation material inhibits the transfer of heat through the hot water pipe. In residential applications, usually the first five feet of pipe closest to the domestic water heater are insulated. Small pipes are insulated with cylindrical half-sections of insulation with factory applied jackets that form a hinge-and-lap or with flexible closed cell material.
Water Heating	Water Heater – Tank Blanket/Insulation	Insulation levels on automatic storage heaters can be increased by installing a fiberglass blanket on the outside of the tank. This increase in insulation will reduce standby losses and save energy. Residential water heater insulation is available either by the blanket or by square foot of fiberglass insulation with R-values ranging from 5 to 14.

Table E-1: Residential Energy-Efficiency Measure Descriptions[185]

End-Use	Measure	Description
Water Heating	Water Heater - Electric, High Efficiency	For electric residential hot water heating, common heaters include automatic storage heaters and instantaneous heaters. Automatic storage heaters incorporate the electric heating element, storage tank, outer jacket, insulation, and controls in a single unit and are normally installed without dependence on other hot water storage equipment. Efficient residential electric water heaters are characterized by a high recovery or thermal efficiency and low standby losses (the ratio of heat lost per hour to the content of the stored water).
Appliances	Clothes Washer – High Efficiency	High efficiency clothes washers use superior designs that require less water to get clothes thoroughly clean. These machines use sensors to match the hot water needs to the load, preventing energy waste. There are two designs: top-loading and front-loading. The front-loading is a horizontal axis machine and utilizes significantly less water than the standard vertical axis machines. A horizontal axis clothes washer utilizes a cylinder that rotates horizontally to wash, rinse, and spin the clothes. Further energy and water savings can be achieved through advanced technologies such as inverter-drive or combination washer-dryer units.
Appliances	Dishwasher – High Efficiency	High efficiency dishwashers save by using both improved technology for the primary wash cycle, and by using less hot water to clean. Construction includes more effective washing action, energy-efficient motors, and other advanced technology such as sensors that determine the length of the wash cycle and the temperature of the water necessary to clean the dishes.
Appliances	Home Office Equipment – Higher Efficiency	In the average home, 90% of the energy used to power electronic products is consumed when the products are turned off - energy used to maintain features like clock, remote control, and channel/station memory. High efficiency consumer electronics can drastically reduce consumption during standby mode, in addition to increasing operation through advanced power management during normal use. Furthermore, computers are responsible for an increasing share of power consumption as the penetration of PC's in the KSA grows and the performance requirements rise. Power supplies for specialty gaming systems, for example, draw as much as 750 W of power, resulting in 6570 kWh per year if the unit runs continuously. Improved power management can significantly reduce the annual consumption of a Personal Computer, in both standby and normal operation.
Appliances	Range and Oven – Electric, Higher Efficiency	These products have additional insulation in the oven compartment and tighter-fitting oven door gaskets and hinges to save energy. Conventional ovens must first heat up about 35 pounds of steel and a large amount of air before they heat up the food. Tests indicate that only 6% of the energy output of a typical oven is actually absorbed by the food. In this analysis, high-efficiency range and oven are assumed to consume 20% less energy than a standard range and oven.
Appliances	Refrigerator/Freezer – Higher Efficiency	An energy-efficient refrigerator/freezer is designed by improving the various components of the cabinet and refrigeration system. These component improvements include cabinet insulation, compressor efficiency, evaporator fan efficiency, defrost controls, mullion heaters, oversized condenser coils, and improved door seals. In the US, the Energy Star Program has a system for labeling refrigerator/freezer units that are energy efficient. In this analysis, a high efficiency refrigerator is assumed to consume 15% (approximately 156 kWh per year) less than a standard refrigerator. Further efficiency increases can be obtained by reducing the volume of refrigerated space, or adding multiple compartments to reduce losses from opening doors.
Appliances	TVs and Home Electronics – Higher Efficiency	In the average home, 90% of the energy used to power electronic products is consumed when the products are turned off - energy used to maintain features like clock, remote control, and channel/station memory. High efficiency electronic products can drastically reduce consumption during standby mode, in addition to increasing operation through advanced power management during normal use.

Table E-2: Commercial Energy-Efficiency Measure Descriptions[186]

End-Use	Energy Efficiency Measure	Description
Cooling	Split Air Conditioning – High Efficiency	Split system air conditioners for the commercial sector are configured in the same manner as they were described for the residential sector. The main difference in the KSA is that they have significant variation in their sizing, with some split systems reaching to 50-60 tons per unit. Most systems however tend to be somewhat smaller on average but are typically larger than residential applications. The EER values appropriate for commercial applications used for this study are as follows: baseline=7.96; high efficiency=10.6. These values were based on information collected during limited field visits while in the KSA over the course of this study. Cost data are based on estimates from US sources, with appropriate modifications to represent cost conditions in the KSA.
Cooling	Packaged Air Conditioning – High Efficiency	Packaged cooling systems are simple to install and maintain, and are commonly used in small to medium-sized commercial buildings. Applications range from a single supply system with air intake filters, supply fan, and cooling coil, or can become more complex with the addition of a return air duct, return air fan, and various controls to optimize performance. For this analysis, units with Energy Efficiency Ratios (EER) of 8.5 and higher were considered, as well as ductless or "mini-split" systems with variable refrigerant flow. The high efficiency units had an EER value of 10.1
Cooling	Chiller – High Efficiency	Commercial buildings are often cooled with a central chiller plant that creates chilled water for distribution throughout the facility. Chillers can be air source or water source, which include heat rejection via a condenser loop and cooling tower. Because of the wide variety of commercial building types and sizes within the KSA, savings and cost values for efficiency improvements in chiller systems represent an average over air- and water-cooled systems, as well as screw, and reciprocating technologies. Under this simplified approach, each central system is characterized by an aggregate efficiency value (inclusive of chiller, pumps, motors and condenser loop equipment), ranging from 1.35 kW/ton to 0.85 kW/ton, with a further efficiency upgrade through the application of variable refrigerant flow technology. The typical range of chiller capacity in a commercial building is around 500 tons/square foot. There are typically multiple chiller units in a commercial building, with each unit being a in a size category of ranging from 500-1,000 tons.
Cooling	District Cooling	District cooling delivers chilled water to condenser units in buildings such as offices and retail facilities needing cooling. Much like the central chiller described above, the operating principles of district cooling are very much the same. As such, for the purposes of this study, the same energy savings as indicated above for chillers applies for district cooling. The only difference is that the chiller plants tend to be significantly larger in size, with a total capacity of 50,000 to 60,000 tons for district cooling developments in the KSA.
Cooling	Chiller, Variable Speed Drive	Centrifugal chillers are driven by electric motors. Motor speed can be adjusted by a variable speed drive (VSD) motor speed controller on a centrifugal chiller. VSD's can be used for capacity control over a fairly small band near the chiller's full load capacity.
Cooling	Cooling Tower, High-Efficiency Fans	Cooling towers typically use banks of fans, each feeding cooling cells. In the cells the fan moves outside air through a spray of water, allowing heat to dissipate from the water. A high efficiency motor using a variable speed drive can improve operating efficiency. Specific fan designs will also make a difference on the overall efficiency performance of the cooling tower.

[186] *Ibid.*

Table E-2: Commercial Energy-Efficiency Measure Descriptions[186]

End-Use	Energy Efficiency Measure	Description
Cooling	Condenser Water, Temperature Reset	Chilled water reset controls save energy by improving chiller performance through increasing the supply chilled water temperature, which allows increased suction pressure during low load periods. Raising the chilled water temperature also reduces chilled water piping losses. The primary savings from the chilled water reset measure results from chiller efficiency improvement. This is due partly to the smaller temperature difference between chilled water and ambient air, and partly due to the sensitivity of chiller performance to suction temperature.
Cooling	Economizer, Installation	Economizers allow outside air (when it is cool and dry enough) to be brought into the building space to meet cooling loads instead of using mechanically cooled interior air. A dual enthalpy economizer consists of indoor and outdoor temperature and humidity sensors, dampers, motors, and motor controls. Economizers are most applicable to temperate climates and savings will be smaller in extremely hot or humid areas. In this analysis, the baseline is assumed to have no economizer.
Ventilation	Fans, Energy-Efficient Motors	High-efficiency motors are essentially interchangeable with standard motors, but differences in construction make them more efficient. Energy-efficient motors achieve their improved efficiency by reducing the losses that occur in the conversion of electrical energy to mechanical energy.
Ventilation	Fans, Variable Speed Control	In a central, forced-air HVAC system, variable air-volume systems respond to changes in cooling loads by reducing the amount of conditioned air flowing to the space (rather than by keeping the airflow constant and varying the temperature of the supply air as with constant-volume air systems). This measure saves electricity by reducing airflow rates during the entire year.
Cooling	HVAC Retrocommissioning	Over time, the complex mechanical systems providind heating and cooling to commercial spaces become mismatched to the loads they are serving as a result of deteriorating equipment, clogged filters, changing demands and schedules, and pressure imbalances. Retrocommissioning is a comprehensive analysis of an entire system in which an engineer assesses shortcomings in system performance, then optimizes through a process of tune-up, maintenance, and reprogramming of control or automation software. Energy efficiency programs throughout the country promote retrocommissioning as a means of greatly reducing energy consumption in existing buildings; for this analysis, a retrocommissioning project is assumed to save 15% of the energy used for HVAC.
Cooling	Pumps – Variable Speed Control	The part-load efficiency of chilled water loop pumps can be improved substantially by varying the speed of the motor drive according to the building demand for cooling. There is also a reduction in piping losses associated with this measure that has a major impact on the energy use for a building. However, pump speeds can generally only be reduced to a minimum specified rate, because chillers and the control valves may require a minimum flow rate to operate. There are two major types of variable speed drives: mechanical and electronic. An additional benefit of variable-speed drives is the ability to start and stop the motor gradually, thus extending the life of the motor and associated machinery. This analysis assumes that electronic variable speed drives are installed.
Cooling	Water Temperature Reset	Chilled water reset controls save energy by improving chiller performance through increasing the supply chilled water temperature, which allows increased suction pressure during low load periods. Raising the chilled water temperature also reduces chilled water piping losses. However, the primary savings from the chilled water reset measure results from chiller efficiency improvement. This is due partly to the smaller temperature difference between chilled water and ambient air, and partly due to the sensitivity of chiller performance to suction temperature.

Table E-2: Commercial Energy-Efficiency Measure Descriptions[186]

End-Use	Energy Efficiency Measure	Description
Cooling	Thermostat – Clock, Programmable	A programmable thermostat can be added to most cooling systems. They are typically used during the summer to increase temperatures during the afternoon. There are two-setting models, and well as models that allow separate programming for each day of the week. The energy savings from this type of thermostat are identical to those of a "setback" strategy with standard thermostats, but the convenience of a programable thermostat makes it a much more attractive option. In this analysis, the baseline is assumed to have no thermostat setback.
Lighting	Compact Fluorescent Lamps	Compact fluorescent lamps can consist of either electronic or magnetic ballast and a twin tube or quad tube lamp. They are designed to be a replacement for standard incandescent lamps and use about 25% of the energy used by incandescent lamps to produce the same lumen output. Integral compact fluorescent lamps have the ballast integrated into the base of the lamp and have a standard screw-in base and a spiral design which permits installation into existing incandescent fixtures.
Lighting	Fluorescent, High Bay Fixtures	The new fluorescent fixtures designed for high-bay applications have several advantages over similar HID fixtures: lower energy consumption, lower lumen depreciation rates, better dimming options, faster start-up and restrike, better color rendition, more pupil lumens, and reduced glare. Not only do these advantages make fluorescent fixtures more cost-effective in many applications, they also enable them to provide superior lighting to the spaces they illuminate.
Lighting	Fluorescent, T8 Lamps and Electronic Ballasts	T8 fluorescent lamps are smaller in diameter than standard T12 lamps, which result in greater light output per watt input (more efficient lighting). T8 lamps also operate at a lower current and wattage, which also increases the efficiency of the ballast but requires the lamps to be compatible with the ballast. Fluorescent lamp fixtures can include a reflector that increases the light output from the fixture, and thus making it possible to use a fewer number of lamps in each fixture. T5 lamps further increase efficiency by reducing the lamp diameter. Based on limited field observations in the KSA for this project, there might be a significant number of T10 lamp configurations as well.
Lighting	LED Lamps	LED lighting has seen recent penetration in specific applications such as traffic lights and exit signs. With the potential for extremely high conversion efficiency, LED's show promise to provide general use white lighting for interior spaces. Current models commercially available have efficacies comparable to CFL's. However, theoretical efficiencies are significantly higher. White LED models under development are expected to provide efficacies greater than 80 lumens per watt.
Lighting	LED Exit Lighting	The lamps inside exit signs represent a significant energy end-use, since they usually operate 24 hours per day. Many old exit signs use incandescent lamps, which consume approximately 40 watts per sign. The incandescent lamps can be replaced with LED lamps that are specially designed for this specific purpose. In comparison, the LED lamps consume approximately 2-5 watts.
Lighting	Metal Halide Lighting	Metal halide lamps are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than from mercury gas alone. Pulse-start metal halide lighting systems typically consume 20 percent less energy than standard metal halide systems. This new technology produces the same intensity at a lower wattage.
Refrigeration	Compressor – High Efficiency	Standard compressors typically operate at approximately 65% efficiency. High-efficiency models are available that can improve compressor efficiency by 15%.

Table E-2: Commercial Energy-Efficiency Measure Descriptions[186]

End-Use	Energy Efficiency Measure	Description
Refrigeration	Compressor – Variable Speed	The part-load efficiency of refrigeration systems can be improved substantially by varying the speed of the motor drive according to the demand for refrigerant, particularly in cold storage applications where many food products do not require constant refrigeration. VSDs for refrigeration systems can lead to significant efficiency improvements relative to standard or even high efficiency compressors.
Refrigeration	Demand Defrost	Defrosting is a procedure, performed periodically on refrigerators and freezers to maintain their operating efficiency. Over time, as the door is opened and closed, letting in new air, water vapor from the air condenses on the cooling elements within the cabinet. It also refers to leaving frozen food at a higher temperature prior to cooking. Most commercial refrigeration systems have automatic defrost processes that cycle on regardless of the need for the defrosting. Demand defrost controls allow the user to select when defrost cycles occur, thus potentially saving energy.
Refrigeration	Anti-sweat Heater Controls	Anti-sweat heaters are used in virtually all low-temperature display cases and many medium-temperature cases to control humidity and prevent the condensation of water vapor on the sides and doors and on the products contained in the cases. Typically, these heaters stay on all the time, even though they only need to be on about half the time. Anti-sweat heater controls can come in the form of humidity sensors or timeclocks.
Refrigeration	Floating Head Pressure Controls	Floating head pressure control allows the pressure in the condenser to "float" with ambient temperatures. This method reduces refrigeration compression ratios, improves system efficiency and extends the compressor life. The greatest savings with a floating head pressure approach occurs when the ambient temperatures are low, such as in the winter season. Floating head pressure control is most practical for new installations. However, retrofits installation can be completed with some existing refrigeration systems. Installing floating head pressure control increases the capacity of the compressor when temperatures are low, which may lead to short cycling.
Refrigeration	Evaporator Fan Control	All refrigeration systems have fans that act to evaporate dampness inside the units and thus prevent the food products from becoming moist and potentially compromised. Most systems have fans that are automatic and cycle on an off based on usage. More modern refrigeration systems can include control functionality that will allow the user to set the fan schedule thus potentially saving significant amounts of energy.
Refrigeration	Strip Curtains	Strip curtains can be used to shield multi-deck display cases for refrigerated items in supermarkets. In addition, they can be used for walk-in refrigerators in other commercial facilities such as restaurants, institutional buildings and the like. In the past, retail facility operators (e.g., supermarkets) were reluctant to close refrigerated cases because they feared that any obstruction would impede customers from reaching (and buying) refrigerated products. However, the energy savings resulting from keeping the cooling in the refrigerated area are potentially significant.
Building Shell	Insulation – Ceiling	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. Typical insulating materials include: loose-fill (blown) cellulose; loose-fill (blown) fiberglass; and rigid polystyrene.
Building Shell	Insulation – Ducting	Duct insulation includes applications such as fiberglass blankets applied to the exterior of the ducts. These measures result in reduced heat gain into the ducting transporting the cool air. Sealing measures are typically accompanied by the action thus reducing the possibility of air leakage and leading to significant energy savings.

Table E-2: Commercial Energy-Efficiency Measure Descriptions[186]

End-Use	Energy Efficiency Measure	Description
Building Shell	Insulation – Radiant Barrier	Radiant barriers are materials that are installed in buildings to reduce summer heat gain and hence to reduce building cooling energy usage. The potential benefit of attic radiant barriers is primarily in reducing air-conditioning loads in warm or hot climates. Radiant barriers usually consist of a thin sheet or coating of a highly reflective material, usually aluminum, applied to one or both sides of a number of substrate materials. These substrates include kraft paper, plastic films, cardboard, plywood sheathing, and air infiltration barrier material. Some products are fiber reinforced to increase the durability and ease of handling.
Building Shell	Insulation – Wall Cavity	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. Typical insulating materials include: loose-fill (blown) cellulose; loose-fill (blown) fiberglass; and rigid polystyrene.
Building Shell	Roofs – High Reflectivity	The color and material of a building structure surface will determine the amount of solar radiation absorbed by that surface. This is called solar absorptance. By painting the roof with a light color (and a lower solar absorptance), the roof will absorb less solar radiation and consequently reduce the cooling load.
Building Shell	Windows – High Efficiency	High-efficiency windows, such as those labeled under the US-based Energy Star Program, are designed to reduce a building's energy bill while increasing comfort for the occupants at the same time. High-efficiency windows have reducing properties that reduce the amount of heat transfer through the glazing surface. For example, some windows have a low-E coating, which is a thin film of metallic oxide coating on the glass surface that allows passage of short-wave solar energy through glass and prevents long-wave energy from escaping. Another example is double-pane glass that reduces conductive and convective heat transfer. There are also double-pane glasses that are gas-filled (usually argon) to further increase the insulating properties of the window.

Table E-3: Government Energy-Efficiency Measure Descriptions[187]

End-Use	Energy Efficiency Measure	Description
Cooling	Split Air Conditioning – High Efficiency	Split system air conditioners for the government sector are configured in the same manner as they were described for the residential sector. The main difference in the KSA is that they have significant variation in their sizing, with some split systems reaching to 50-60 tons per unit. Most systems however tend to be somewhat smaller on average but are typically larger than residential applications. The EER values appropriate for commercial applications used for this study are as follows: baseline=7.96; high efficiency=10.6. These values were based on information collected during limited field visits while in the KSA over the course of this study. Cost data are based on estimates from US sources, with appropriate modifications to represent cost conditions in the KSA.
Cooling	Packaged Air Conditioning – High Efficiency	Packaged cooling systems are simple to install and maintain, and are commonly used in small to medium-sized government buildings. Applications range from a single supply system with air intake filters, supply fan, and cooling coil, or can become more complex with the addition of a return air duct, return air fan, and various controls to optimize performance. For this analysis, units with Energy Efficiency Ratios (EER) of 8.5 and higher were considered, as well as ductless or "mini-split" systems with variable refrigerant flow. The high efficiency units had an EER value of 10.1
Cooling	Chiller – High Efficiency	Commercial buildings are often cooled with a central chiller plant that creates chilled water for distribution throughout the facility. Chillers can be air source or water source, which include heat rejection via a condenser loop and cooling tower. Because of the wide variety of commercial building types and sizes within the KSA, savings and cost values for efficiency improvements in chiller systems represent an average over air- and water-cooled systems, as well as screw, and reciprocating technologies. Under this simplified approach, each central system is characterized by an aggregate efficiency value (inclusive of chiller, pumps, motors and condenser loop equipment), ranging from 1.35 kW/ton to 0.85 kW/ton, with a further efficiency upgrade through the application of variable refrigerant flow technology. The typical range of chiller capacity in a government building is around 500 tons/square foot. There are typically multiple chiller units in a commercial building, with each unit being a in a size category of ranging from 500-1,000 tons.
Cooling	District Cooling	District cooling delivers chilled water to condenser units in buildings such as government office parks requiring cooling. Much like the central chiller described above, the operating principles of district cooling are very much the same. As such, for the purposes of this study, the same energy savings as indicated above for chillers applies for district cooling. The only difference is that the chiller plants tend to be significantly larger in size, with a total capacity of 50,000 to 60,000 tons for district cooling developments in the KSA.
Cooling	Chiller, Variable Speed Drive	Centrifugal chillers are driven by electric motors. Motor speed can be adjusted by a variable speed drive (VSD) motor speed controller on a centrifugal chiller. VSD's can be used for capacity control over a fairly small band near the chiller's full load capacity.
Cooling	Cooling Tower, High-Efficiency Fans	Cooling towers typically use banks of fans, each feeding cooling cells. In the cells the fan moves outside air through a spray of water, allowing heat to dissipate from the water. A high efficiency motor using a variable speed drive can improve operating efficiency. Specific fan designs will also make a difference on the overall efficiency performance of the cooling tower.

[187] *Ibid.*

Table E-3: Government Energy-Efficiency Measure Descriptions[187]

End-Use	Energy Efficiency Measure	Description
Cooling	Condenser Water, Temperature Reset	Chilled water reset controls save energy by improving chiller performance through increasing the supply chilled water temperature, which allows increased suction pressure during low load periods. Raising the chilled water temperature also reduces chilled water piping losses. The primary savings from the chilled water reset measure results from chiller efficiency improvement. This is due partly to the smaller temperature difference between chilled water and ambient air, and partly due to the sensitivity of chiller performance to suction temperature.
Cooling	Economizer, Installation	Economizers allow outside air (when it is cool and dry enough) to be brought into the building space to meet cooling loads instead of using mechanically cooled interior air. A dual enthalpy economizer consists of indoor and outdoor temperature and humidity sensors, dampers, motors, and motor controls. Economizers are most applicable to temperate climates and savings will be smaller in extremely hot or humid areas. In this analysis, the baseline is assumed to have no economizer.
Ventilation	Fans, Energy-Efficient Motors	High-efficiency motors are essentially interchangeable with standard motors, but differences in construction make them more efficient. Energy-efficient motors achieve their improved efficiency by reducing the losses that occur in the conversion of electrical energy to mechanical energy.
Ventilation	Fans, Variable Speed Control	In a central, forced-air HVAC system, variable air-volume systems respond to changes in cooling loads by reducing the amount of conditioned air flowing to the space (rather than by keeping the airflow constant and varying the temperature of the supply air as with constant-volume air systems). This measure saves electricity by reducing airflow rates during the entire year.
Cooling	HVAC Retrocommissioning	Over time, the complex mechanical systems providing heating and cooling to government spaces become mismatched to the loads they are serving as a result of deteriorating equipment, clogged filters, changing demands and schedules, and pressure imbalances. Retrocommissioning is a comprehensive analysis of an entire system in which an engineer assesses shortcomings in system performance, then optimizes through a process of tune-up, maintenance, and reprogramming of control or automation software. Energy efficiency programs throughout the country promote retrocommissioning as a means of greatly reducing energy consumption in existing buildings; for this analysis, a retrocommissioning project is assumed to save 15% of the energy used for HVAC.
Cooling	Pumps – Variable Speed Control	The part-load efficiency of chilled water loop pumps can be improved substantially by varying the speed of the motor drive according to the building demand for cooling. There is also a reduction in piping losses associated with this measure that has a major impact on the energy use for a building. However, pump speeds can generally only be reduced to a minimum specified rate, because chillers and the control valves may require a minimum flow rate to operate. There are two major types of variable speed drives: mechanical and electronic. An additional benefit of variable-speed drives is the ability to start and stop the motor gradually, thus extending the life of the motor and associated machinery. This analysis assumes that electronic variable speed drives are installed.
Cooling	Water Temperature Reset	Chilled water reset controls save energy by improving chiller performance through increasing the supply chilled water temperature, which allows increased suction pressure during low load periods. Raising the chilled water temperature also reduces chilled water piping losses. However, the primary savings from the chilled water reset measure results from chiller efficiency improvement. This is due partly to the smaller temperature difference between chilled water and ambient air, and partly due to the sensitivity of chiller performance to suction temperature.

Table E-3: Government Energy-Efficiency Measure Descriptions[187]

End-Use	Energy Efficiency Measure	Description
Cooling	Thermostat – Clock, Programmable	A programmable thermostat can be added to most cooling systems. They are typically used during the summer to increase temperatures during the afternoon. There are two-setting models, and well as models that allow separate programming for each day of the week. The energy savings from this type of thermostat are identical to those of a "setback" strategy with standard thermostats, but the convenience of a programable thermostat makes it a much more attractive option. In this analysis, the baseline is assumed to have no thermostat setback.
Lighting	Compact Fluorescent Lamps	Compact fluorescent lamps can consist of either electronic or magnetic ballast and a twin tube or quad tube lamp. They are designed to be a replacement for standard incandescent lamps and use about 25% of the energy used by incandescent lamps to produce the same lumen output. Integral compact fluorescent lamps have the ballast integrated into the base of the lamp and have a standard screw-in base and a spiral design which permits installation into existing incandescent fixtures.
Lighting	Fluorescent, High Bay Fixtures	The new fluorescent fixtures designed for high-bay applications have several advantages over similar HID fixtures: lower energy consumption, lower lumen depreciation rates, better dimming options, faster start-up and restrike, better color rendition, more pupil lumens, and reduced glare. Not only do these advantages make fluorescent fixtures more cost-effective in many applications, they also enable them to provide superior lighting to the spaces they illuminate.
Lighting	Fluorescent, T8 Lamps and Electronic Ballasts	T8 fluorescent lamps are smaller in diameter than standard T12 lamps, which result in greater light output per watt input (more efficient lighting). T8 lamps also operate at a lower current and wattage, which also increases the efficiency of the ballast but requires the lamps to be compatible with the ballast. Fluorescent lamp fixtures can include a reflector that increases the light output from the fixture, and thus making it possible to use a fewer number of lamps in each fixture. T5 lamps further increase efficiency by reducing the lamp diameter. Based on limited field observations in the KSA for this project, there might be a significant number of T10 lamp configurations as well.
Lighting	LED Lamps	LED lighting has seen recent penetration in specific applications such as traffic lights and exit signs. With the potential for extremely high conversion efficiency, LED's show promise to provide general use white lighting for interior spaces. Current models commercially available have efficacies comparable to CFL's. However, theoretical efficiencies are significantly higher. White LED models under development are expected to provide efficacies greater than 80 lumens per watt.
Lighting	LED Exit Lighting	The lamps inside exit signs represent a significant energy end-use, since they usually operate 24 hours per day. Many old exit signs use incandescent lamps, which consume approximately 40 watts per sign. The incandescent lamps can be replaced with LED lamps that are specially designed for this specific purpose. In comparison, the LED lamps consume approximately 2-5 watts.
Lighting	Metal Halide Lighting	Metal halide lamps are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than from mercury gas alone. Pulse-start metal halide lighting systems typically consume 20 percent less energy than standard metal halide systems. This new technology produces the same intensity at a lower wattage.

Table E-3: Government Energy-Efficiency Measure Descriptions[187]

End-Use	Energy Efficiency Measure	Description
Lighting	Municipal Streetlighting – Metal Halide	Metal halide lamps are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than from mercury gas alone. Pulse-start metal halide lighting systems typically consume 20 percent less energy than standard metal halide systems. This new technology produces the same intensity at a lower wattage.
Lighting	Municipal Streetlighting – High Pressure Sodium	High-pressure sodium lamps (HPS) have been used outdoors to replace mercury vapor flood lamps. Their high luminous efficacy has also led to their use in commercial buildings ranging from warehouses to office buildings. However, their poor color rendition is often cited as a constraint on their use in retail establishments. HPS is commonly used to light roadways, parking lots, and pathways, and for security, industrial and warehouse lighting applications. Since they operate well in cold temperatures, they can be good as retrofits for exterior incandescent and mercury vapor lighting.
Lighting	Municipal Streetlighting – LEDs	LED streetlights perform better than incandescent models. Compared to standard incandescent signals, LED streetlights use 80-90% less energy, rarely fail, and have a lower maintenance cost.
Other	Municipal Pumping	The following list defines the areas where municipal water management improvements can be broadly applied: • Pipe Sizing – Friction in the main pipes can increase the energy that is needed to move water. When planning water system improvements, such as main replacements, the pipe length, diameter, and roughness need to be evaluated. Piping components and design, such as valves and unnecessary flow paths, can also impact frictional losses in the distribution system. • Inflow and Infiltration monitoring (I/I) - I/I causes flows to increase which causes pumps in lift stations to operate longer and may require larger pumps or multiple pumps to handle their higher flows. Replacing cracked mains and fixing manholes to reduce I/I problems will reduce energy used to run pumps at lift stations and the treatment plant. • System Topography - Water systems with multiple pressure zones due to the topography of the area have higher energy costs. Energy costs are increased to operate booster-pumping stations to increase water pressure. Energy efficient variable speed drives for pumps that can adjust to variable flows and pressure conditions can reduce these energy costs. • Water Loss – Monitoring the water loss on a regular basis can help leaks or inaccurate meters to reduce energy costs associated with pumping and treating water that is not being sold. Monthly comparisons between the amount of water that is pumped and treated versus the water that is sold to customers can help identify any losses.
Building Shell	Insulation – Ceiling	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. Typical insulating materials include: loose-fill (blown) cellulose; loose-fill (blown) fiberglass; and rigid polystyrene.
Building Shell	Insulation – Ducting	Duct insulation includes applications such as fiberglass blankets applied to the exterior of the ducts. These measures result in reduced heat gain into the ducting transporting the cool air. Sealing measures are typically accompanied by the action thus reducing the possibility of air leakage and leading to significant energy savings.

Table E-3: Government Energy-Efficiency Measure Descriptions[187]

End-Use	Energy Efficiency Measure	Description
Building Shell	Insulation – Radiant Barrier	Radiant barriers are materials that are installed in buildings to reduce summer heat gain and hence to reduce building cooling energy usage. The potential benefit of attic radiant barriers is primarily in reducing air-conditioning loads in warm or hot climates. Radiant barriers usually consist of a thin sheet or coating of a highly reflective material, usually aluminum, applied to one or both sides of a number of substrate materials. These substrates include kraft paper, plastic films, cardboard, plywood sheathing, and air infiltration barrier material. Some products are fiber reinforced to increase the durability and ease of handling.
Building Shell	Insulation – Wall Cavity	Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. Thus, thermal insulation can conserve energy by reducing the heat loss or gain of a building. The type of building construction defines insulating possibilities. Typical insulating materials include: loose-fill (blown) cellulose; loose-fill (blown) fiberglass; and rigid polystyrene.
Building Shell	Roofs – High Reflectivity	The color and material of a building structure surface will determine the amount of solar radiation absorbed by that surface. This is called solar absorptance. By painting the roof with a light color (and a lower solar absorptance), the roof will absorb less solar radiation and consequently reduce the cooling load.
Building Shell	Windows – High Efficiency	High-efficiency windows, such as those labeled under the US-based Energy Star Program, are designed to reduce a building's energy bill while increasing comfort for the occupants at the same time. High-efficiency windows have reducing properties that reduce the amount of heat transfer through the glazing surface. For example, some windows have a low-E coating, which is a thin film of metallic oxide coating on the glass surface that allows passage of short-wave solar energy through glass and prevents long-wave energy from escaping. Another example is double-pane glass that reduces conductive and convective heat transfer. There are also double-pane glasses that are gas-filled (usually argon) to further increase the insulating properties of the window.
Office Equipment	Personal Computing Equipment	Energy Star labeled office equipment saves energy by powering down and "going to sleep" when not in use. ENERGY STAR labeled computers automatically power down to 15 watts or less when not in use and may actually last longer than conventional products because they spend a large portion of time in a low-power sleep mode. ENERGY STAR labeled computers also generate less heat than conventional models. The ClimateSavers Initiative, made up of leading computer processor manufacturers, has stated a goal of reducing power consumption in active mode by 50% by integrating innovative power management into the chip design process.
Office Equipment	Printers and Copiers	Energy Star labeled office equipment saves energy by powering down and "going to sleep" when not in use. ENERGY STAR labeled copiers are equipped with a feature that allows them to automatically turn off after a period of inactivity, reducing a copier's annual electricity costs by over 60%. High-speed copiers that include a duplexing unit that is set to automatically make double-sided copies can reduce paper costs by $60 a month and help to save trees.

Table E-4: Industrial Energy-Efficiency Measure Descriptions[188]

End-Use	Energy Efficiency Measure	Description
Cooling	Packaged Air Conditioning – High Efficiency	Packaged cooling systems are simple to install and maintain, and are the most common cooling methods used for industrial facilities. Applications range from a single supply system with air intake filters, supply fan, and cooling coil, or can become more complex with the addition of a return air duct, return air fan, and various controls to optimize performance. For this analysis, units with Energy Efficiency Ratios (EER) of 8.5 and higher were considered, as well as ductless or "mini-split" systems with variable refrigerant flow. The high efficiency units had an EER value of 10.1
Cooling	Chiller – High Efficiency	Industrial facilities are occasionally cooled with a central chiller plant that creates chilled water for distribution throughout the facility. Chillers can be air source or water source, which include heat rejection via a condenser loop and cooling tower. Because of the wide variety of commercial building types and sizes within the KSA, savings and cost values for efficiency improvements in chiller systems represent an average over air- and water-cooled systems, as well as screw, and reciprocating technologies. Under this simplified approach, each central system is characterized by an aggregate efficiency value (inclusive of chiller, pumps, motors and condenser loop equipment), ranging from 1.35 kW/ton to 0.85 kW/ton, with a further efficiency upgrade through the application of variable refrigerant flow technology. The typical range of chiller capacity in a government building is around 500 tons/square foot. There are typically multiple chiller units in a commercial building, with each unit being a in a size category of ranging from 500-1,000 tons.
Cooling	Chiller, Variable Speed Drive	Centrifugal chillers are driven by electric motors. Motor speed can be adjusted by a variable speed drive (VSD) motor speed controller on a centrifugal chiller. VSD's can be used for capacity control over a fairly small band near the chiller's full load capacity.
Cooling	Cooling Tower, High-Efficiency Fans	Cooling towers typically use banks of fans, each feeding cooling cells. In the cells the fan moves outside air through a spray of water, allowing heat to dissipate from the water. A high efficiency motor using a variable speed drive can improve operating efficiency. Specific fan designs will also make a difference on the overall efficiency performance of the cooling tower.
Cooling	Condenser Water, Temperature Reset	Chilled water reset controls save energy by improving chiller performance through increasing the supply chilled water temperature, which allows increased suction pressure during low load periods. Raising the chilled water temperature also reduces chilled water piping losses. The primary savings from the chilled water reset measure results from chiller efficiency improvement. This is due partly to the smaller temperature difference between chilled water and ambient air, and partly due to the sensitivity of chiller performance to suction temperature.
Cooling	Economizer, Installation	Economizers allow outside air (when it is cool and dry enough) to be brought into the building space to meet cooling loads instead of using mechanically cooled interior air. A dual enthalpy economizer consists of indoor and outdoor temperature and humidity sensors, dampers, motors, and motor controls. Economizers are most applicable to temperate climates and savings will be smaller in extremely hot or humid areas. In this analysis, the baseline is assumed to have no economizer.

[188] *Ibid.*

Table E-4: Industrial Energy-Efficiency Measure Descriptions[188]

End-Use	Energy Efficiency Measure	Description
Ventilation	Fans, Energy-Efficient Motors	High-efficiency motors are essentially interchangeable with standard motors, but differences in construction make them more efficient. Energy-efficient motors achieve their improved efficiency by reducing the losses that occur in the conversion of electrical energy to mechanical energy.
Ventilation	Fans, Variable Speed Control	In a central, forced-air HVAC system, variable air-volume systems respond to changes in cooling loads by reducing the amount of conditioned air flowing to the space (rather than by keeping the airflow constant and varying the temperature of the supply air as with constant-volume air systems). This measure saves electricity by reducing airflow rates during the entire year.
Cooling	HVAC Retrocommissioning	Over time, the complex mechanical systems providing heating and cooling to government spaces become mismatched to the loads they are serving as a result of deteriorating equipment, clogged filters, changing demands and schedules, and pressure imbalances. Retrocommissioning is a comprehensive analysis of an entire system in which an engineer assesses shortcomings in system performance, then optimizes through a process of tune-up, maintenance, and reprogramming of control or automation software. Energy efficiency programs throughout the country promote retrocommissioning as a means of greatly reducing energy consumption in existing buildings; for this analysis, a retrocommissioning project is assumed to save 15% of the energy used for HVAC.
Cooling	Pumps – Variable Speed Control	The part-load efficiency of chilled water loop pumps can be improved substantially by varying the speed of the motor drive according to the building demand for cooling. There is also a reduction in piping losses associated with this measure that has a major impact on the energy use for a building. However, pump speeds can generally only be reduced to a minimum specified rate, because chillers and the control valves may require a minimum flow rate to operate. There are two major types of variable speed drives: mechanical and electronic. An additional benefit of variable-speed drives is the ability to start and stop the motor gradually, thus extending the life of the motor and associated machinery. This analysis assumes that electronic variable speed drives are installed.
Lighting	Compact Fluorescent Lamps	Compact fluorescent lamps can consist of either electronic or magnetic ballast and a twin tube or quad tube lamp. They are designed to be a replacement for standard incandescent lamps and use about 25% of the energy used by incandescent lamps to produce the same lumen output. Integral compact fluorescent lamps have the ballast integrated into the base of the lamp and have a standard screw-in base and a spiral design which permits installation into existing incandescent fixtures.
Lighting	Fluorescent, High Bay Fixtures	The new fluorescent fixtures designed for high-bay applications have several advantages over similar HID fixtures: lower energy consumption, lower lumen depreciation rates, better dimming options, faster start-up and restrike, better color rendition, more pupil lumens, and reduced glare. Not only do these advantages make fluorescent fixtures more cost-effective in many applications, they also enable them to provide superior lighting to the spaces they illuminate.
Lighting	Fluorescent, T8 Lamps and Electronic Ballasts	T8 fluorescent lamps are smaller in diameter than standard T12 lamps, which result in greater light output per watt input (more efficient lighting). T8 lamps also operate at a lower current and wattage, which also increases the efficiency of the ballast but requires the lamps to be compatible with the ballast. Fluorescent lamp fixtures can include a reflector that increases the light output from the fixture, and thus making it possible to use a fewer number of lamps in each fixture. T5 lamps further increase efficiency by reducing the lamp diameter. Based on limited field observations in the KSA for this project, there might be a significant number of T10 lamp configurations as well.

Table E-4: Industrial Energy-Efficiency Measure Descriptions[188]

End-Use	Energy Efficiency Measure	Description
Lighting	LED Lamps	LED lighting has seen recent penetration in specific applications such as traffic lights and exit signs. With the potential for extremely high conversion efficiency, LED's show promise to provide general use white lighting for interior spaces. Current models commercially available have efficacies comparable to CFL's. However, theoretical efficiencies are significantly higher. White LED models under development are expected to provide efficacies greater than 80 lumens per watt.
Lighting	LED Exit Lighting	The lamps inside exit signs represent a significant energy end-use, since they usually operate 24 hours per day. Many old exit signs use incandescent lamps, which consume approximately 40 watts per sign. The incandescent lamps can be replaced with LED lamps that are specially designed for this specific purpose. In comparison, the LED lamps consume approximately 2-5 watts.
Lighting	Metal Halide Lighting	Metal halide lamps are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than from mercury gas alone. Pulse-start metal halide lighting systems typically consume 20 percent less energy than standard metal halide systems. This new technology produces the same intensity at a lower wattage.
Industrial Process	High Efficiency Motors	High efficiency motors reduce the amount of lost energy going into heat rather than power. Since less heat is generated, less energy is needed to cool the motor with a fan. Therefore, the initial cost of energy efficient motors is generally higher than for standard motors. However their life-cycle costs can make them far more economical because of savings they generate in operating expense. High efficiency motors can provide savings of 0.5% to 3% over standard motors. The savings results from the fact that energy efficient motors run cooler than their standard counterparts, resulting in an increase in the life of the motor insulation and bearing. In general, an efficient motor is a more reliable motor because there are fewer winding failures, longer periods between needed maintenance, and fewer forced outages. For example, using copper instead of aluminum in the windings, and increasing conductor cross-sectional area, lowers a motor's I2R losses.

APPENDIX F: SENSITIVITY ANALYSIS

The cost-effectiveness and market potential estimates presented in this study are based on the best available primary and secondary data. However, as with any study of this nature, there is uncertainty around exactly what will be achieved by the programs in the KSA. To address uncertainty in the key variables of our study, we performed a sensitivity analysis. The focus of the analysis is on the programs that were selected for full deployment in the short term. Specifically, we perform sensitivity analysis around assumed participation rates and per-customer impacts.

The approach is to establish a feasible high and low range for each key input variable. For example, consider the residential DLC measure. This study's base case estimate of peak reductions for each customer participating in the residential DLC measure is 2.7 kW. However, based on a review of utility impacts in other regions, the range of impacts could be 40 percent higher or lower than this.[189] Reasons for this range of impacts could be differences in climates or air-conditioner cycling strategies. A similar range of uncertainty exists around the assumed participation rate. The eligible population of customers is assumed to be five percent based on estimates of residential CAC saturation. It is not likely lower than five percent, but a recent NEEP study has suggested that it could be as high as 17 percent. Similarly, while the base case assumption for participation among eligible customers is 20 percent, other utilities are projecting participation rates as high as 30 percent or as low as 10 percent. The program-level impact estimate and TRC cost-effectiveness assessment were then conducted at these lower- and upper-bounds to produce new estimates of market potential and cost-effectiveness.

A similar approach was used to establish upper- and lower-bounds for each of the LM/DR measures considered for short-term implementation. For LM/DR programs, participation will be highly dependent on the extent to which the programs are marketed. Per-customer impacts for programs that do not explicitly involve a control technology (interruptible tariffs and curtailable load management) will depend on Saudi customer behavior, for which there is limited information. Below, we describe how the ranges were established.

Residential DLC

- CAC saturation could be as high as 17% (from NEEP study) but is probably not lower than the base case estimate of 5%
- Program participation could be as high as 30% or as low as 10% (based on a review of utility LM/DR filings and projections)
- Per-customer impacts across utilities are typically between 40% lower (a peak impact of 1.6 kW) and 40% higher (a peak impact of 3.8 kW) than the average value (based on FERC DR survey)

Commercial and Government DLC

- Eligible customer population estimates are reasonable and not modified for sensitivity analysis
- Acceptance rates could be as low as 5% or as high as 20% (general assumption)

[189] Based on a review of LM/DR program impacts reported in the 2008 FERC survey.

- Range of per-customer impacts is likely similar to that of residential, increasing or decreasing by 40%

Commercial and Government Interruptible Tariffs
- Participation could be as high as 20% or as low as 2% (2008 FERC Survey)
- Per-customer impacts could be as high as 90% or as low as 15% (2008 FERC Survey)

Industrial Interruptible Tariffs
- Participation could be as high as 30% or as low as 10% (2008 FERC Survey)
- Per-customer impacts could be as high as 90% or as low as 15% (2008 FERC Survey)

Industrial Curtailable Load Management
- Participation could be as high as 50% or as low as 10% (2008 FERC Survey)
- Per-customer impacts could be as high as 90% or as low as 15% (2008 FERC Survey)

We used a broader approach to establishing the ranges for the EE programs. For these programs, there is a lower degree of uncertainty around the per-unit impacts, since these are largely engineering-based estimates that are tailored to the climate and existing equipment efficiency of the KSA. To recognize that there is some degree of uncertainty that is introduced when making these adjustments for climate and equipment efficiency, and to provide feel for the sensitivity of the analysis to changes in these assumptions, the per-unit impacts were scaled up and down by 20 percent.

There is a greater degree of uncertainty in the assumed market acceptance rates for the EE programs. Market acceptance will depend on how aggressively the efficiency programs are marketed, and possibly more importantly, how strictly new codes and standards are enforced. Additionally, the expected improvements in customer energy awareness in the KSA are a significant question mark and further contribute to uncertainty in these participation figures. To represent the general degree of uncertainty in assumed participation, the market acceptance rates were scaled up and down by 50 percent. Eligibility rates (i.e. the percent of customers with the applicable equipment or technology) were held constant.[190]

The results are estimates of market potential that are above and below the base case estimates presented in Chapter 12 of this study. These results are summarized in Figure F-1. Even at the very low end of the range of expectations, the programs could be expected to deliver over 2,000 MW of peak reduction by 2021. The potential upside for the programs is much higher, in excess of 20 GW.

190 The one exception is residential CAC saturation, which was adjusted using the same assumptions in the residential DLC sensitivity analysis.

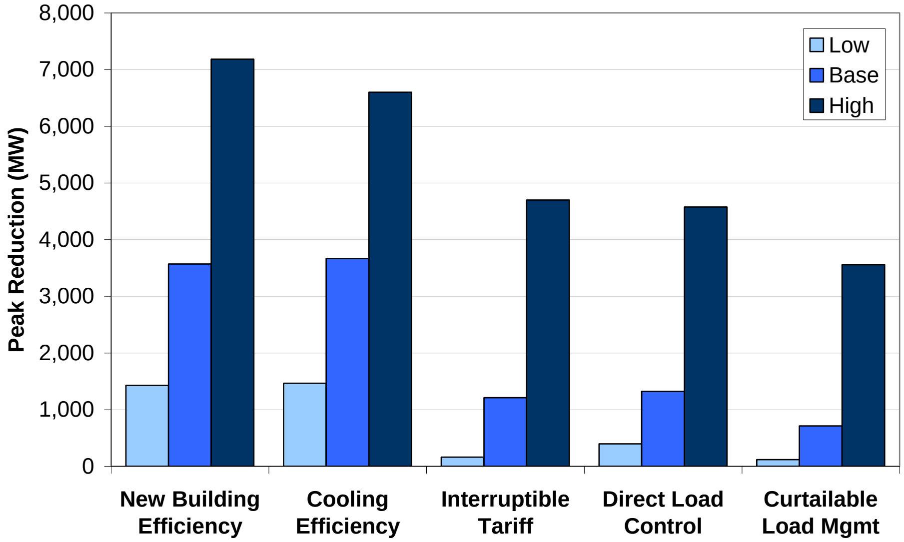


Figure F-1: Range of Peak Impacts from DSM Programs (2021)

Changes in impacts also lead to changes in the benefit-cost ratios of each program. The resulting TRC benefit-cost ratios are presented in Figure F-2.[191] This figure provides some sense of the level of sensitivity of the cost effectiveness to the impacts. However, it does not capture the full dynamics of how the cost-effectiveness would change if impacts from the programs vary. Specifically, LM/DR programs that are not appearing to be cost-effective at the low end of the range (i.e. the curtailable load management program) could still in practice pass the cost-effectiveness test under these conditions. By reducing the incentive payments to customers, the costs of the LM/DR programs would be reduced, therefore improving the economics from a societal perspective.

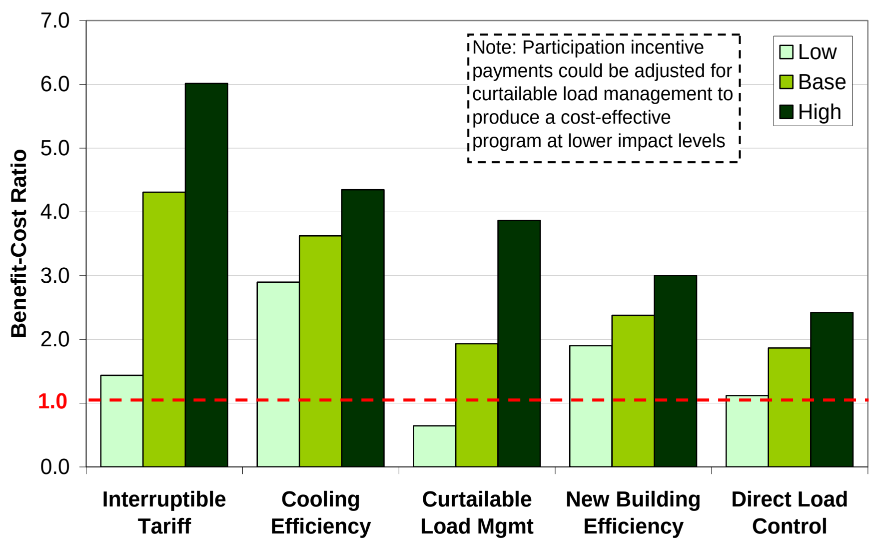


Figure F-2: Range of TRC Benefit-Cost Ratios from DSM Programs

[191] Benefits are calculated using the market (or "shadow") prices of energy.

These estimates are provided to illustrate the general range of impacts that might be expected from these programs. They should be considered indicative of the magnitude of the range, rather than being interpreted literally as point estimates. Further research with the programs in the KSA, through pilots or full-scale deployment, is the best way to move forward with reducing this uncertainty and building confidence in their impacts.

APPENDIX G: EXAMPLE LM/DR MEASURE SCREENING CALCULATIONS

This appendix contains examples of calculations of the economic screening and potential estimation for three LM/DR measures. These measures are residential direct load control, industrial curtailable load management, and commercial thermal energy storage (see next page).

Table G-1: Residential DLC Valuation Model

Avoided Cost Estimates		
Capacity	**SR/kW-yr**	
T&D	85	
Peaker	236	
Energy	**TOU hours**	**SR/MWh**
Summer Peak	500	60
Summer Off-Peak	3150	50
Winter Peak	700	40
Winter Off-Peak	4410	35

Financial Assumptions	
Life (yrs)	20
Discount Rate	10.0%

Per-Customer Impact Estimate		
Typical per-customer impact (KSA)	2.7	kW
Assumed change in energy	0	kWh/yr

Measure Cost (per-customer)	
Equipment cost	750
Import cost adder	15%
Program cost adder	15%
Total program cost (per customer)	975

Measure Benefit (per-customer)	
Annual capacity benefit	867
Annual energy benefit	0
Total annual benefit	867
PV total benefit	7,378

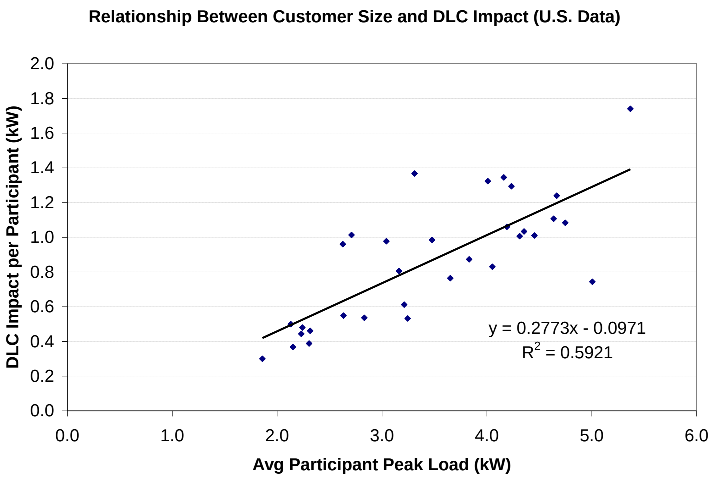
Benefit-Cost Ratio	
B-C Ratio	7.6

Participation	
# of residential customers (2012)	5,374,761
% with CAC	5%
Participation (of eligible)	20%
Total participating	53,748

Market Potential	
Peak reduction potential (MW)	145

Note: Blue indicates calculation, black indicates assumption

To estimate the likely per-customer impact of direct load control in the KSA, impacts of U.S. air-conditioning DLC programs were scaled to reflect the larger size of customers in the KSA. Figure G-1 below explains how this calculation was performed.



Source: 2008 FERC Survey of U.S. Utilities

Steps in Scaling DLC Impacts

Average KSA residential customer coincident peak demand = **5.4 kW**

Average CAC customer will be larger than this… ratio of CAC customer peak to non-CAC customer peak in hot climates of US = **2.3-to-1**

Therefore, average KSA CAC customer peak =
2.3 x 5.4 = **12.4 kW**

Implied KSA DLC impact =
0.2273 x 11.9 – 0.0971 =
2.7 kW (see relationship in chart at left)

Figure G-1: Approach to Developing KSA-Specific DLC Impacts

Table G-2: Thermal Energy Storage Valuation Model

Avoided Cost Estimates		
Capacity	**SR/kW-yr**	
T&D	85	
Peaker	236	
Energy	**TOU hours**	**SR/MWh**
Summer Peak	500	60
Summer Off-Peak	3150	50
Winter Peak	700	40
Winter Off-Peak	4410	35

Financial Assumptions	
Life (yrs)	20
Discount Rate	10.0%

Measure Cost	
Equipment cost per kW	7,500
Import cost adder	15%
Program cost adder	15%

Intermediate Calculations	
Annual capacity benefit	321
Annual energy benefit	58
Annual energy cost	50
Annual net energy benefit	9
PV capacity benefit	2,733
PV net energy benefit	72

Final Output	
PV Total benefit	2,805
PV Total cost	9,750
B-C Ratio	0.3

Note: Blue indicates calculation, black indicates assumption

Table G-3: Industrial Curtailable Load Management Valuation Model

Avoided Cost Estimates		
Capacity	**SR/kW-yr**	
T&D	85	
Peaker	236	
Energy	**TOU hours**	**SR/MWh**
Summer Peak	500	60
Summer Off-Peak	3150	50
Winter Peak	700	40
Winter Off-Peak	4410	35

Financial Assumptions	
Life (yrs)	20
Discount Rate	10.0%

Per-Customer Impact Estimate		
Per-customer impact (% of peak)	45%	
Avg industrial customer peak	1,071	kW
Typical per-customer impact (KSA)	481.8	kW
Assumed change in energy	0	kWh/yr

Measure Cost (per-customer)	
Equipment cost	56,250
Import cost adder	15%
Program cost adder	15%
Total program cost (per customer)	73,125

Measure Benefit (per-customer)	
Annual capacity benefit	154,628
Annual energy benefit	0
Total annual benefit	154,628
PV total benefit	1,316,432

Benefit-Cost Ratio	
B-C Ratio	18.0

Participation	
# of industrial customers (2012)	8,321
% participating	20%
Total participating	1,664

Market Potential	
Peak reduction potential (MW)	802

Note: Blue indicates calculation, black indicates assumption

APPENDIX H: THE PRISM TOOL

To simulate customer response to TOU rates, *The Brattle Group* relied on the Price Impact Simulation Model (PRISM).[192] The PRISM software captures the actual responses of thousands of customers on time-varying rates during several recent pricing experiments across North America. The responses from these experiments were tailored specifically to Saudi Arabia's system characteristics and rates to produce likely estimates of load shape impacts for the average customer.

Dynamic pricing pilots conducted around the globe have scientifically shown that customers do reduce peak consumption when enrolled in time-varying rates. In the past decade, these pilots have tested the effectiveness of various rate designs (e.g. TOU, CPP, RTP) and technologies (e.g. smart thermostat, in-home information display). The 17 pilots included thousands of residential customers and tested 70 combinations of rates and technologies. The results of the pilots are illustrated in Figure H-1.

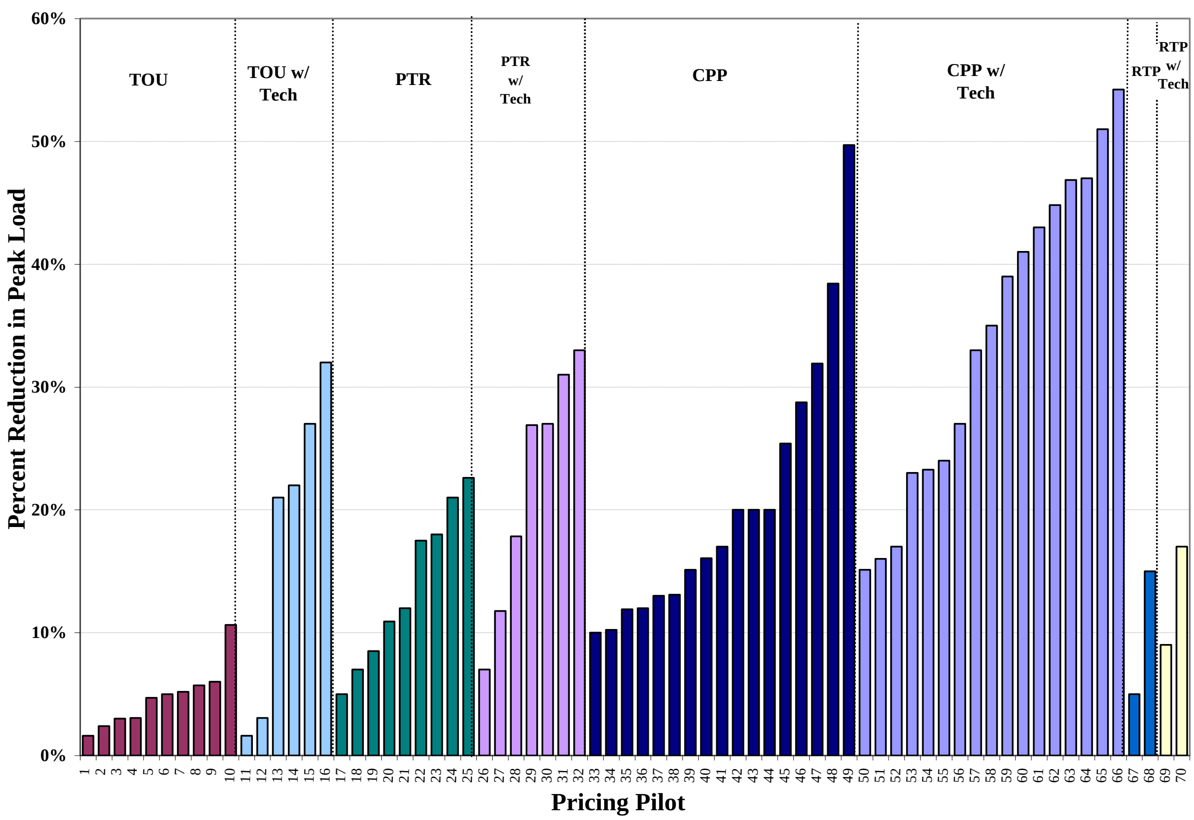


Figure H-1: The Results of Residential Dynamic Pricing Pilots

PRISM captures the results of these pilots and simulates two distinct impacts on customer usage patterns. The first is called the "substitution effect," which captures a customer's decision to shift usage from higher priced peak periods to lower priced off-peak periods. The second impact is

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192 Recently, PRISM formed the basis for FERC's "A National Assessment of Demand Response Potential." For more information about the model, see Ahmad Faruqui, John Tsoukalis, and Ryan Hledik, "The Power of Dynamic Pricing," *The Electricity Journal*, April 2009.

called the "daily effect" and captures the overall change in usage (i.e. conservation or load building) that is induced by differences in the average daily price of the new rate relative to the existing rate. The magnitude of these impacts depends on the structure of the dynamic rate that is being tested, as well as a number of factors that influence the relative price responsiveness a utility's customers (such as weather, central air conditioning (CAC) saturation, or presence of enabling technologies). For example, higher peak-to-off-peak price differentials produce greater reductions in peak demand. Additionally, the presence of enabling technology, such as programmable communicating thermostats (PCTs) or in-home displays (IHDs) will enhance a customer's ability to respond to price signals, either through automation or increased access to usage-related information.

Figure H-2 illustrates the PRISM modeling framework, starting first with the basic model inputs and then identifying how these influence the drivers of the model results, which are a function of the substitution and daily effects.

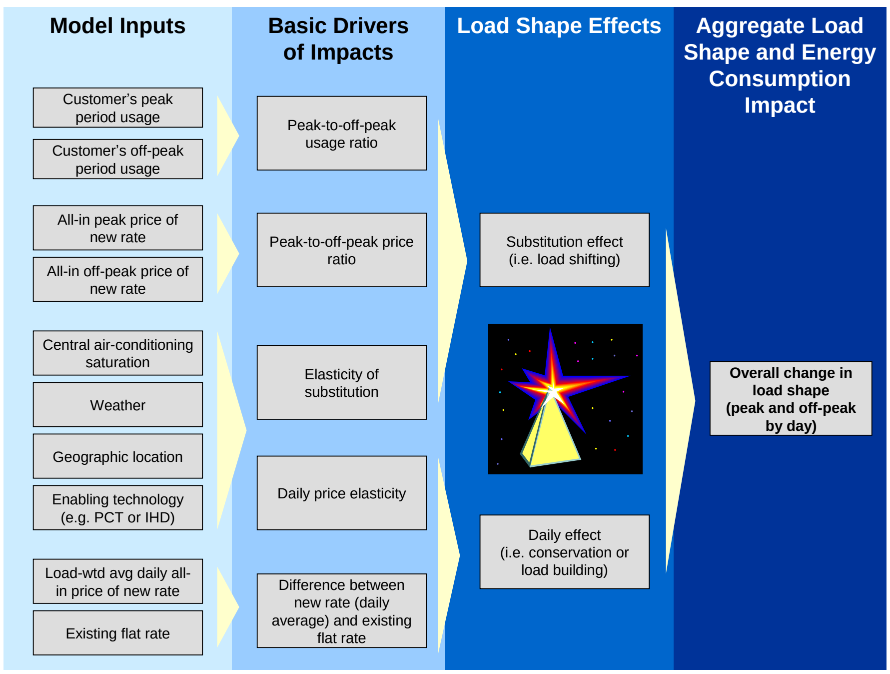

Figure H-2: The PRISM Model - From Inputs to Impacts

The key drivers of customer price responsiveness can be illustrated graphically in the form of "price response curves." As the price ratio of the new time-based rate increases, so does the customer's reduction in peak demand. However, this relationship is not linear. Incremental increases in the peak reduction become progressively smaller as customers begin to run out of additional measures that can be taken. The price response curves are shown in Figure H-3.

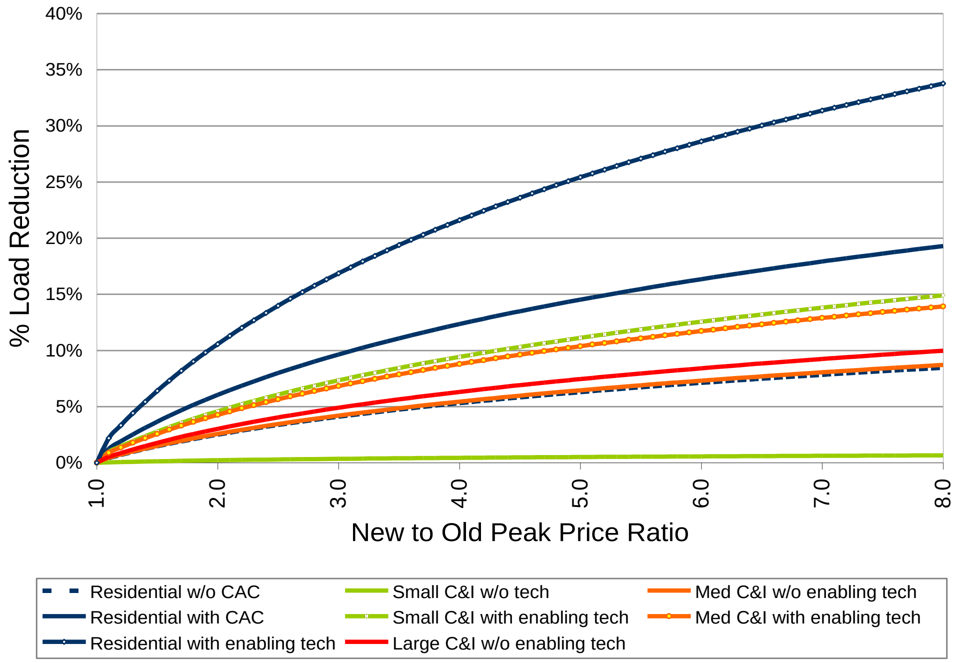

Figure H-3: Simulated Customer Price Response Curves

APPENDIX I: SELECTING AN M&V METHOD

This appendix provides an overview of the issues involved in measuring the impact of DSM programs on customer load profiles. After reviewing five analytical options for doing the measurements, it discusses data requirements and alternative model specifications.

Analytical Options

Once DSM programs have been rolled out in the KSA, it will be important to know whether they have induced any changes in customer patterns of use (load profiles). In order to determine these impacts, the ideal approach will be to take two different measurements of customer load profiles, one featuring before-and-after measurements on the same group of customers and the other featuring side-by-side measurements on a group that was moved to DSM programs and a group that was not moved.

If both measurements are taken, then an estimate of "difference-of-differences" in load shapes can be developed and attributed to the rollout of the DSM program. Such an estimate would net out the effect of changes in other factors that may have occurred simultaneously with the roll-out of the DSM program, such as weather and economic activity.

However, the nature of the rollout of the DSM programs in the KSA presents some unique challenges. It is not a real experiment, in the sense of having treatment and control groups that are observed both before and after the application of the treatment (i.e., the DSM measure). It is more akin to a natural experiment in which the analyst has to abide by the inability to control for the effects of all relevant factors.

Since every customer in the KSA has the option to participate in the DSM programs, there may be challenges with establishing a representative control group of customers who will not participate in any program. This would make it difficult to develop the difference-in-differences estimator. But it is still possible to approximate this ideal standard of measurement by using one or more of the five options that are outlined below.

Option 1. Continuation of load research sample

This method can be used by utilities that have had a load research sample prior to the rollout of DSM programs. They can use the load research sample to describe conditions before DSm programs are rolled out. Once DSM programs have been rolled out to all customers, they will continue monitoring load profiles within the sample. By comparing the load research sample before and after the institution of the DSM programs, estimates of changes in load profiles will be derived.

The analysis could be carried out at the level of individual customers by treating the sample as a panel data set (i.e., as a time series of cross-sections) or at the aggregate level or both. Care would have to be taken to normalize for changing weather conditions. Analytically, a variety of options are available for estimating DSM program impacts with such a data set, including analysis of variance, analysis of covariance and econometric demand models. The latter would also yield estimates of price elasticity and elasticity of substitution.

Option 2. Aggregate load shape changes

This analysis could be carried out by any utility, including those without a pre-existing load research sample. The aggregate load shape, preferably at the residential class level, would be measured before and after the roll-out of DSM programs. If class load profile information is lacking, the analysis could be carried out at the system level. Adjustments would need to be made to account for changing weather conditions and economic factors.

Option 3. New load research sample

If a pre-DSM load research sample does not exist, it may still be useful to create a new load research sample on customers once they have enrolled in DSM programs. Changes in load profiles over the following years would yield evidence on load shape changes that occurred following the rollout of DSM programs. In addition, since the DSM programs may change in the future, the new sample would provide the ideal platform for estimating impacts. The same methodologies listed in Option 1 could be used here.

Option 4. Exploit variation in DSM programs across geographies

To the extent that the DSM programs are rolled out gradually within operating areas, an opportunity arises to have side-by-side measurements on load profiles, in addition to having before-after measurements. The two can be combined to yield difference-in-difference estimates. The key to successful side-by-side measurements is making sure that the treatment and control groups are well-matched.

Option 5. Options may be combined

Of course, each of the previous four options can be pursued individually or combined to maximize the precision of estimation. For example, there may be pre-existing load research sample to pursue Option 1. Additionally, it may also be possible to exploit geographical variation in DSM program rollouts and pursue Option 4. Finally, to the extent that system (or class) load profile data is available it should be possible to pursue Option 2.

Data Requirements

Regardless of which of the six analytical options are pursued, data along the following lines will need to be collected:

- Hourly load profile data, preferably either at the individual customer level in a random sample or at the aggregate class or system level
- The load profiles preferably should be collected before the roll-out of DSM programs and also after the roll-out of DSM programs, as discussed in the section on analytical options
- Socio-demographic characteristics of a sample of customers who are in the load research sample
- Hourly weather data (i.e. dry bulb temperature, dew point)
- DSM incentive levels (including existing rates and new time-based rates, if deployed)

Modeling Approaches

There are two widely used approaches in the literature, ANOVA/ANCOVA methods and econometric demand models. These are briefly discussed below.

ANOVA/ANCOVA Models

The most commonly used impact metric is the difference in usage before and after the treatment is applied. Let us call this D1. Most of the time, D1 is estimated by averaging each customer's individual usage difference.[193] By looking at the variation across customers, a standard deviation (S1) can also be derived to accompany D1. A t-test can then be carried out to judge the statistical significance of D1.

Since D1 may represent changes arising not just from the treatment but from other factors such as the economy, weather or some newsworthy event, it is preferable to also compute D2 (and S2), the difference in usage in the control group before and after the treatment is applied to the treatment group. The ideal measure of impact is therefore derived by netting out the usage changes that have occurred in the control group from the changes that have occurred in the treatment group. This can be expressed as D3 = D1 - D2. S3 can be derived and a t-test carried out to measure statistical significance.

In practice, some people estimate D1 and others estimate D3. The simplest way to measure either D1 or D3 is to carry out an analysis of variance (ANOVA). This involves a statistical comparison of means between the treatment and control groups. This is equivalent to running a regression of usage on a binary variable which takes on the value of 1 if the customer is in the treatment group and 0 if the customer is in the control group. ANOVA yields an estimate of the change in usage that is attributable to the treatment. This can be expressed in nominal terms or in percentage terms. It can be calculated on a customer-by-customer basis or over the entire sample of customers. *This is a strength of the approach*. However, the measurement is specific to the treatment being tested. If the treatment is a specific price during the critical peak hours, let us say a dollar per kWh, then the ANOVA method cannot be used to surmise the impact of higher or lower prices. *This is a limitation of the approach*.

A more sophisticated approach allows for the existence of covariates to further explain the variation in usage. Examples are weather (which varies over time), dwelling type (single family versus multi family), and ownership of key appliances such as central air conditioning and so on. It is often the case that variation in usage over time and across customers is not correlated with the treatment and this tends to weaken the precision of the estimates one gets from ANOVA. Analysis of Covariance (ANCOVA) is designed to correct for this problem. It is likely to yield estimates of impacts with greater precision (lower standard errors).

Econometric Demand Models

Neither ANOVA nor ANCOVA can provide impact estimates for treatments other than those tested in the experiment. However, utility executives and policy makers will often want to know

[193] In some cases, the analyst may wish to focus on customer-specific usage differences.

what would happen in the future if other prices or incentives payments are used.[194] In order to obtain such estimates, price elasticities and demand curves have to be estimated. These can be estimated in one of two ways -- first, using single equations which explain the behavior of usage as a function of price in that period and perhaps in related periods and, second, using systems of equations derived from the theory of utility maximization. In both cases, the regression models exploit the price variation over time and across customers to parameterize the demand functions. The more price variation in the models, the more precise will be the parameter estimates. Thus, the experimental design will ideally feature more than one price per pricing period. However, it may be possible to obtain price elasticities even within a single price per period since the control group will provide yet another price as will the treatment group in the pre-treatment period.

Demand equations can be estimated using the data on both treatment and control groups to predict the price elasticity of customers. If pre-treatment data are available, they can be used to adjust for any pre-existing differences between the treatment and control groups. Furthermore, weather data in conjunction with data on the presence of enabling technologies such as the Energy Orb and programmable communicating thermostats and customer socio-demographic variables may also be used to explain variations in individual customers' demand for electricity.

Demand models allow for estimation of the impact of prices other than those used in the program and this is *the main strength of these models* as opposed to alternative methods such as ANOVA/ANCOVA. The transfer of the available information from existing prices to other potential prices is made possible by the use of price elasticities.

There are several types of demand elasticities. The *own price elasticity* of demand measures the percent change in demand of a good due to a one percent change in the price of the given good after controlling for all other factors that could potentially affect the demand for the good. The *cross price elasticity* measures the percent change in demand of a good due to a one percent change in the price of a related good. In single equation models, the own price and cross price elasticity are estimated separately for peak and off-peak periods.

For demand systems, a slightly different approach is used. There is one equation that measures changes in daily energy consumption and another equation that measures changes in the load shape. The *daily price elasticity* is used to measure changes in daily usage. The *elasticity of substitution*, measures the percent change in the ratio of consumption between two periods due to the change in the ratio of prices between these two periods, is used to measure changes in load shape. The two equations are jointly estimated. Predictions about demand response are made by solving the equations for values of peak and off-peak consumption.

In order to infer demand curves and elasticities, it is necessary to have price variation in the sample. The greater the variation in prices, the higher the precision in the estimated elasticities and demand curves. Ideally, one would test multiple price points for each pricing period. However, it is still possible to estimate demand price elasticities with a single pricing treatment

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194 Load curtailment can be encouraged through prices, through a dynamic rate like CPP, or through incentive payments, as is done with curtailable load management programs. In this section, the term "price" is used to refer generally to the level of the financial incentive under both approaches. However, the approach described in this section is most applicable to time-based rate programs.

as long as there is another price for the control group and/or the pre-treatment period. However, with just two price points, only linear demand curves can be estimated.

Another choice that needs to be made is the procedure for econometric estimation of the elasticities after the demand model is specified. In a framework which includes a cross section of customers over time, one of the panel (or cross-sectional time-series) estimation routines can be used[195]. Fixed effects and random effect models are two widely used panel regression estimation routines. *Fixed effects* estimation uses a data transformation method that removes any unobserved time-invariant effect that has a potential impact on the dependent variable. This model is suitable when these unobserved time invariant effects are expected to be correlated with the other explanatory variables in the model. The alternative is the *random effects* routine which is based on the postulation that the unobserved time invariant effects are random and are not correlated with other explanatory variables of the model. Statistical tests are available for guiding the choice of the two estimation methods.

In addition to the panel estimation, the question of estimating customer-by-customer demand functions often comes up. When the model is estimated at the customer-by-customer level, the estimation sample does not constitute a panel but reduces to simple time-series estimation. The customer-specific elasticity estimation is only feasible to do if there is sufficient price variation over time on a customer-by-customer basis. For instance, if one is working with real time pricing data which features hourly price variation, the estimation of customer-specific elasticities is feasible. However, if there is only one price per period for each customer, then estimating price elasticities that are customer specific is problematic and may well be empirically impossible.

Another question deals with the choice of functional form of the demand equations. One specification which is well grounded in economic theory and which has been widely estimated in the econometric literature on time-varying prices is the constant elasticity-of-substitution (CES) model[196]. The CES modeling system consists of several equations, all but one of which measure substitution between adjacent periods and/or hours within a day and one of which measures changes in daily energy consumption. The substitution equations capture pure changes in load shape within a day whereas the daily equation captures overall energy conservation or load building. The CES system captures the non-linearity in the relationship between demand response and dynamic prices.

Besides the CES model discussed above, other more complex options used in the literature include the Cobb-Douglas, Trans-log, Generalized Leontief (Diewert), and Generalized McFadden functional forms.[197] The nature of the problem at hand and the policy making context will usually determine which of these widely-used functional forms are best suited for the specific application. The following criteria can be used to guide the choice of functional form:

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195 For more information on the panel data estimation, see Jeffrey M. Wooldridge, *Econometric Analysis of Cross Section and Panel Data*, Cambridge: Massachusetts 2002.

196 The CES model has a strong pedigree and two of its developers went on to win the Nobel Prize in economics.

197 See "Production Economics: A Dual Approach to Theory and Applications," Volume 1, edited by Melvyn Fuss and Daniel McFadden, Netherlands: North-Holland Publishing Company-1978.

- Parsimony in parameters: a functional form should not have numerous parameters as this will increase the likelihood of the multicollinearity problem. Moreover when the sample size is small, excess parameters imply lost degrees of freedom.
- Ease of interpretation: excessively complex functional forms may contain irregularities which may not be easily detected in the richness of parameters. Also, complex transformations may make it computationally difficult to derive certain parameters of interest such as elasticities of substitution.
- Computational ease: models linear in parameters have a computational cost advantage as well as a more developed statistical theory. The trade-off between the computational requirements versus statistical soundness must be carefully made.
- Interpolative robustness: within the range of the observed sample, chosen functional form should produce well-behaved and economically sound parameter estimates such as positive marginal products and negative own price elasticities.
- Extrapolative robustness: functional form should lead to sound estimates consistent with the maintained hypothesis outside the range of observed data. This criterion is particularly important for forecasting exercises.

Demand model estimation yields a comprehensive set of impact metrics. However, *this comes at a cost of requiring expertise in regressions analysis and econometrics*. Project teams should weigh the costs and benefits of each approach accordingly and select the one that conforms best to the project content and constraints.