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PROMOTING ENERGY EFFICIENCY INVESTMENTS FOR CLIMATE CHANGE MITIGATION AND SUSTAINABLE DEVELOPMENT

CASE STUDY: KUWAIT

Analysis of Economical and Environmental Benefits of Promoting Energy Efficiency in Buildings

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Acronyms

A/C: Air Conditioning

CFLs: Compact Fluorescent Lamps

COP: Coefficient of Performance

ECMs: Energy Conservation Measures

EEMs: Energy Efficiency Measures

GCC: Gulf Cooperation Council

HVAC: Heating, Ventilation and Air Conditioning

IEA: International Energy Agency

KD: Kuwaiti Dinar

KISR: Kuwait Institute for Scientific Research

LCC: Life Cycle Cost

MENA: Middle East and North Africa

MEW: Ministry of Electricity and Water

WWR: Window to Wall Ratio

Abstract

In this report, an overview of the Kuwaiti energy sector characteristics is presented to include its generating capacity as well as its end-use consumption over the last two decade. Moreover, a detailed analysis of the total and end-use energy consumption attributed to various building types is provided. The report presents the specific regulations of the building energy conservation code of practice using its original version of 1983 and its revised version of 2010. The code enforcement mechanism is also outlined in the report. Based on a detailed review of the reported literature, the potential energy savings opportunities and their cost-effectiveness for Kuwaiti buildings are discussed. Using a comprehensive series of analyses, the report summarizes the economical and environmental benefits of improving energy efficiency for both new and retrofitted buildings in Kuwait. It is found that the 2010 revised version of the energy conservation code of practice can provide an additional 23% savings compared to the original version of the code developed and implemented in 1983.

Moreover, it is found that without a gradual reduction of energy subsidies, the establishment of a mandatory energy efficiency retrofit program in Kuwaiti through implementation of basic energy efficiency measures and improved operating strategies for the existing building stock can provide significant economical and environmental benefits to Kuwait as well as the creation of significant job opportunities.

Background

Worldwide, buildings account for about 40% of the primary energy consumption. In the Middle East and North Africa (MENA region, buildings consumes even higher fraction of the primary energy consumption. For instance, 70% of total electrical energy consumption in Kuwait is attributed to buildings. Considering all the sectors (i.e., buildings, industry, and transportation), Qatar and Kuwait have the highest per capita carbon emissions in the world as depicted in Figure 1 (WBCDS, 2009).

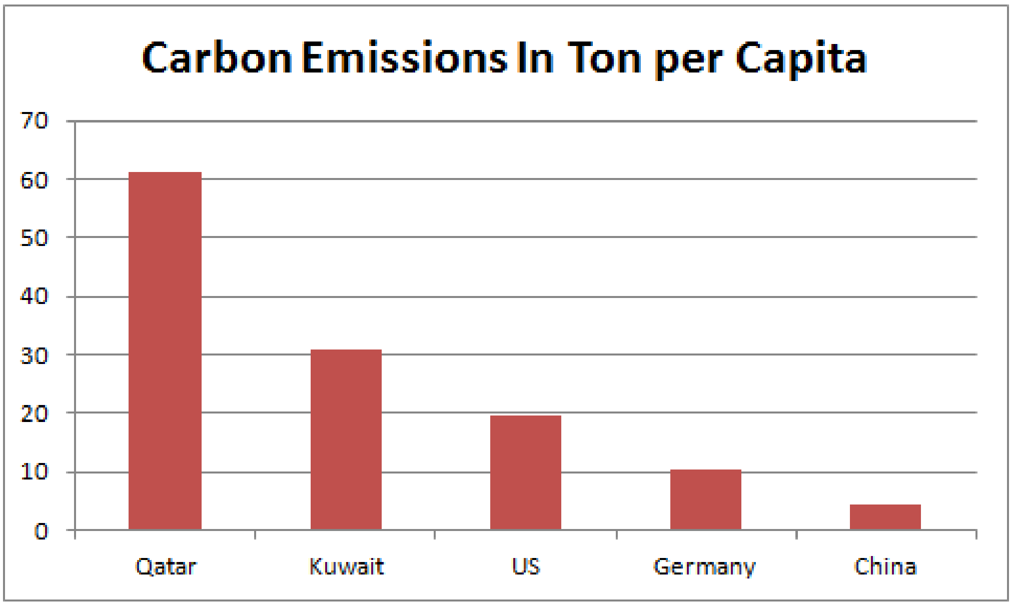


Figure 1: Per Capita Carbon Emissions for Selected Countries

Figure 2 shows the per capita electricity consumption in several MENA countries. It is should be noted that for several MENA countries including Kuwait, the majority of the electrical energy is used to operate buildings (EIA, 2006). The trend for high energy demand for buildings in the Arab region is expected to continue over the next decade due to high population growth and significant urbanization. Indeed, the annual urban population growth rates in Arab countries range between 2 to 6% with an average for the region of 3.8% according to a UN-Habitat report (UN-Habitat, 2012). As a result, the building sector is one of the fastest growing sectors in the Arab region. Specifically, according to a recent report, a total of $4.3 trillion is forecasted to be spent on construction in the MENA region over the next decade, representing a cumulative growth of 80% (Oxford Economics, 2009).

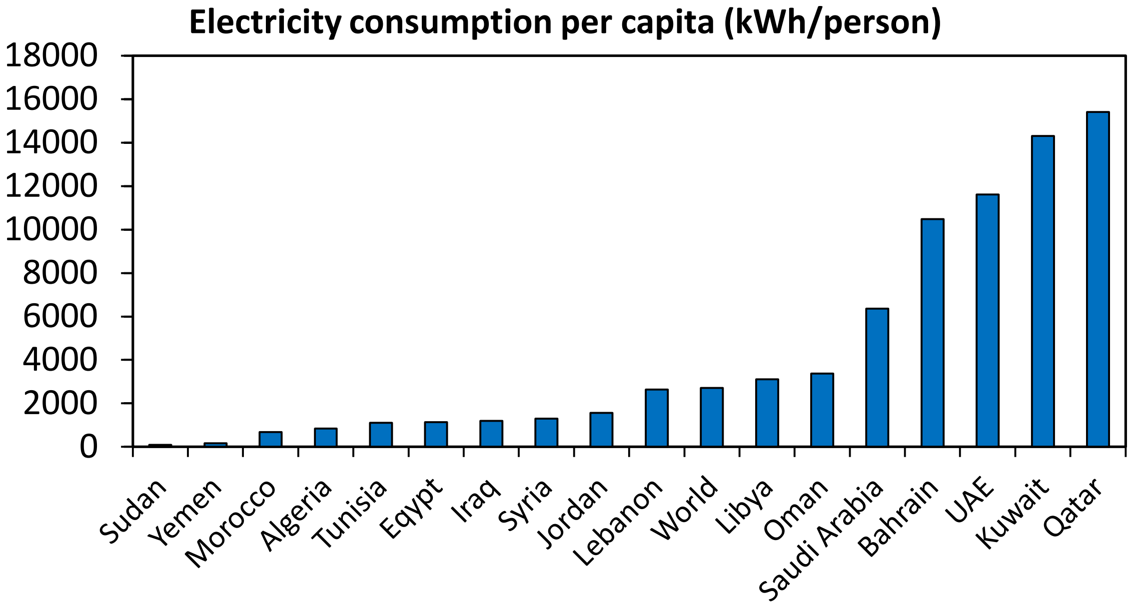


Figure 2: Per Capita Electricity Consumption for Selected MENA Countries (Source: IEA, 2006)

Moreover, several MENA countries provide significant energy subsidies in order to reduce the electricity and fuel prices to their citizens. In particular, United Arab of Emirates (UAE) and Kuwait are the top two countries in the world for energy consumption subsidies per person as illustrated from Figure 3. It is reported that for its 2012/2013 budget, Kuwait allocates KD 3.1 billion of the 6.3 billion susidization for the consumer services to the electricity subsidization (Capital Standards, 2013). It is also reported that the actual costs for generating and distributing electricity in Kuwait during 2011 is 37 fils/kWh (i.e., $0.134/kWh) but it is sold to the customers for only 2 fils (i.e., $006/kWh), resulting in 95% subsidies from the government (MEW, 2011).

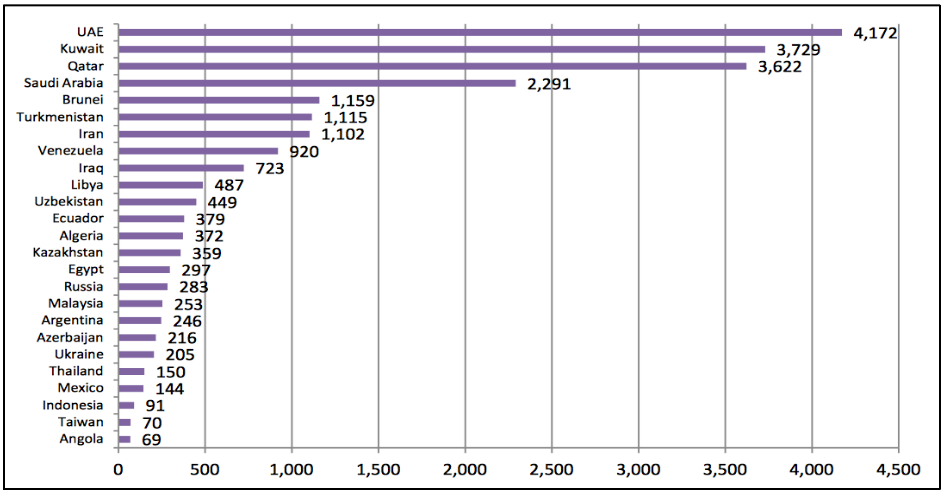


Figure 3: Country Ranking and Level of Energy Consumption Subsidies per Person in US Dollars during 2011 (Source: Capital Standards, 2013)

Energy Sector Characteristics

The Ministry of Electricity and Water (MEW) is the sole supplier of electricity and water resources in Kuwait. The increasing population in Kuwait and the scarce water resources is forcing MEW to increase its generating capacities with higher investments in new power plants. Indeed, over the last decade, Kuwait has seen its population as well as its per capita energy consumption increase steadily as shown in Figure 4. The data obtained from MEW indicate that the energy use per person has more than doubled between 1980 and 2005 (MEW, 2012). Moreover, the population has doubled from 1992 to 2005 due to high demand in labor force after the Iraq invasion of 1990-1991. The growth in the population combined with high energy use by person has significantly increased the requirements for electrical power generation to meet the national needs especially in the growing residential sector.

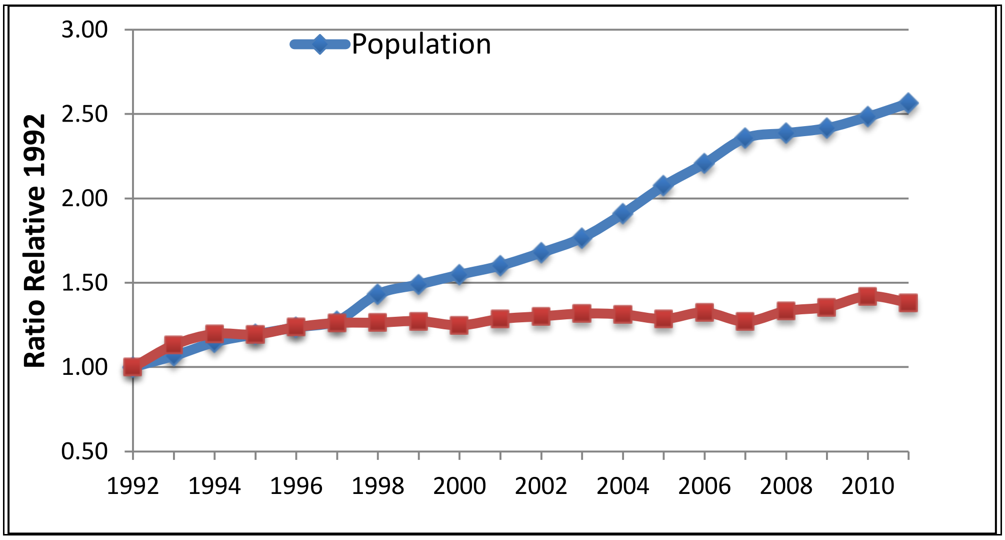


Figure 4: Annual per Capita Energy Use and Population Levels for Kuwait

The seawater desalination process used in Kuwait as well as in most of the gulf region requires about 10 times more energy than surface fresh water production. In 2011, Kuwait had 8 electrical power stations with a combined capacity of 13115 MW serving a peak load of 11220 MW as detailed in Table 1 (MEW, 2012).

Table 1: Electrical Power Stations, their Capacity, and their Peak Load in Kuwait during 2011

Power station	Capacity (MW)	Peak Load on July 27, 2011 (MW)
Shuwaikh Station	120	120
Shuaiba South Station	660	540
Shuaiba North Station	600	600
Doha East Station	1018	770
Doha West Station	2381	1720
Az-Zour South Station	4646	4110
Sabiya Station	3690	3360
All Stations	13115	11220

Kuwait currently utilizes almost 300,000 barrels of oils per day for electricity generation. The consumption is expected to increase to as high as 900,000 barrels per day or 20% of its oil production by 2030, thus significantly reducing oil revenues of the country. Moreover, the total energy subsidies to consumers are estimated to exceed KWD 9 billion by 2030. It is expected that Kuwait may face energy shortage during the summer of 2014 and 2015 if the projects aimed at increasing daily production at Subbiya power plant and the South Az-Zour power plant by 500 megawatts each as well as the construction of the North Zour power plants are not implemented on time (MEW, 2012).

According to an IEA study (IEA, 2012), Kuwait has one of the highest carbon emissions intensity in the MENA region due to its high reliance on oil to produce electricity and desalinate water. Table 2 summarizes the CO_2 emissions intensity expressed in gCO_2/kWh for selected MENA countries during 2009. Kuwait generates 870 of gCO_2 for each kWh of electricity, significantly higher that the world average of 573 gCO_2/kWh. It should be noted that countries that utilize natural gas to generate a significant portion of their electricity have low carbon emissions intensity. For instance, the share of natural gas in the total electricity generated in Qatar is over 85% (IEA, 2012).

Table 2: CO_2 Emissions Intensity for Select MENA Countries

Country	**CO_2 emissions intensity (gCO_2/kWh)**
Libya	872
Kuwait	870
Saudi Arabia	757
Syria	641
UAE	631
Jordan	581
Tunisia	538
Qatar	494
Egypt	466
World (Average)	573

Figure 5 illustrates the annual electrical peak demand variation from 2002 through 2011. A regression analysis of the data indicates that there is a consistent growth rate of the electrical peak demand over the 1980's peak with about 6% average increase rate in the last decade (MEW, 2012). Based on the rate of increase of 6% observed in Figure 5, the annual peak demand is predicted to be 15,000 MW by 2020 and over 20,000 MW (almost double the current peak load) by 2030.

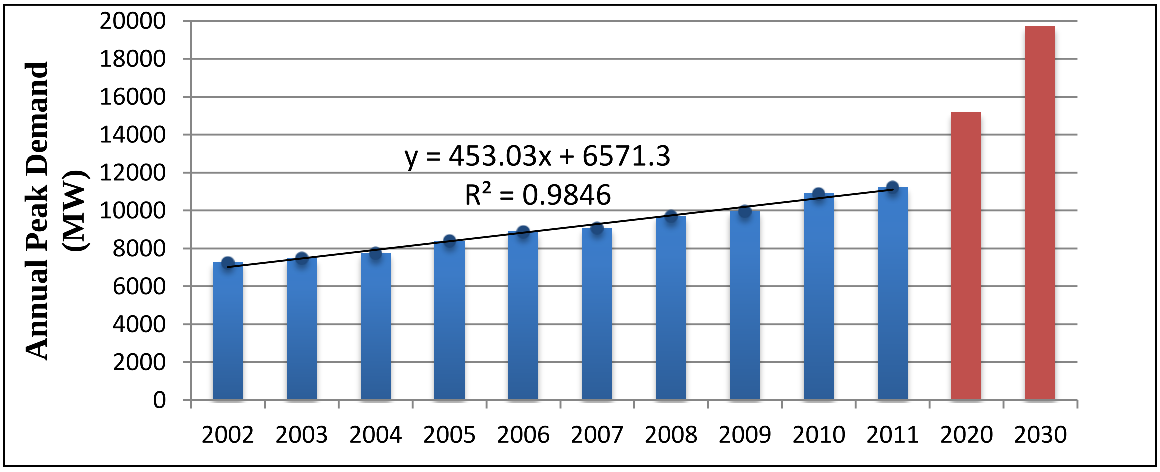


Figure 5: Variation of Annual Electrical Peak Demand between 2002 and 2011 in Kuwait with Projected Peaks for 2020 and 2030

Figure 6 indicates that the residential sector (including the privately owned residences and rental apartment buildings, typically referred to as investment buildings) constitute over 57% of the Kuwaiti peak electrical power in 2011 (MEW, 2012).

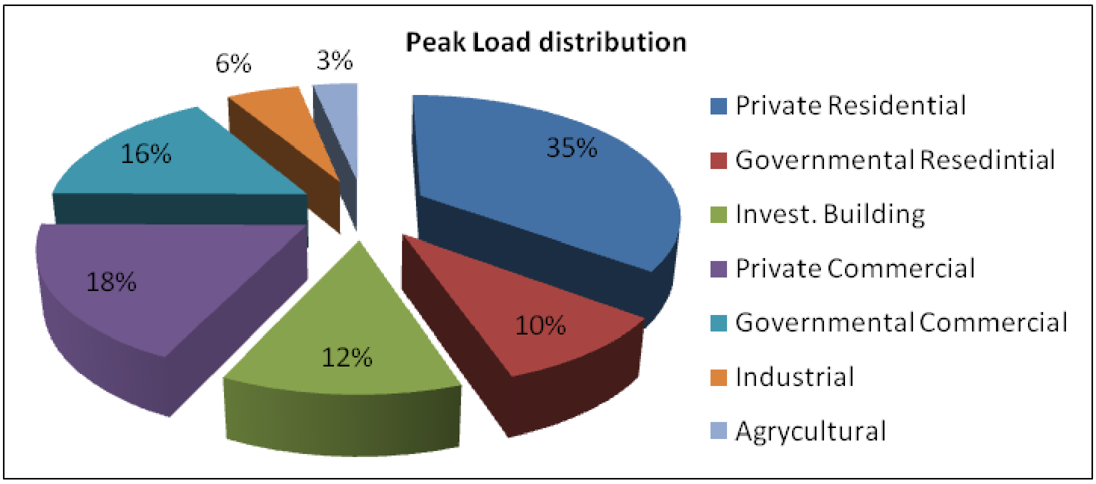


Figure 6: Electrical Demand End-use Distribution in Kuwait during 2011

Table 3 lists number of each type of buildings in the 2011 existing building stock served by MEW. Residential buildings either private or governmental constitute the vast majority of the building stock with about 87% of the total buildings in Kuwait (MEW, 2012).

Table 3: Types and Number of Buildings in Kuwait at the end of 2011

Type	Number of Buildings	Percentage of Total
Private Residential	390,213	86.3%
Governmental Residential	1,448	0.3%
Commercial	45,685	10.1%
Industrial	1,832	0.4%
Agricultural	4,597	1.0%
Services	937	0.2%
Governmental	7,553	1.7%
Total	452,265	100%

It should be noted that a significant portion of the electricity demand and consumption is associated with air conditioning of buildings as clearly illustrated by Figure 7 that correlates the monthly electricity consumption in Kuwait as a function of monthly average outdoor temperature during both years of 2005 and 2011 using 3-parameter inversing modeling approach (Krarti, 2011). During winter months, the energy consumption remains low and flat and is mostly attributed to base-load demands such as lighting, plug loads, and other devices that are operated independently of the outdoor conditions. While, air conditioning energy consumption increases with increasing outdoor temperature during the summer. From 2005 to 2011, the electricity base-load consumption increased by about 36% in Kuwait from 2012.8 GWh to reach 2733.3 GWh mainly due to the increase in the number of buildings associated with growth in population and urbanization.

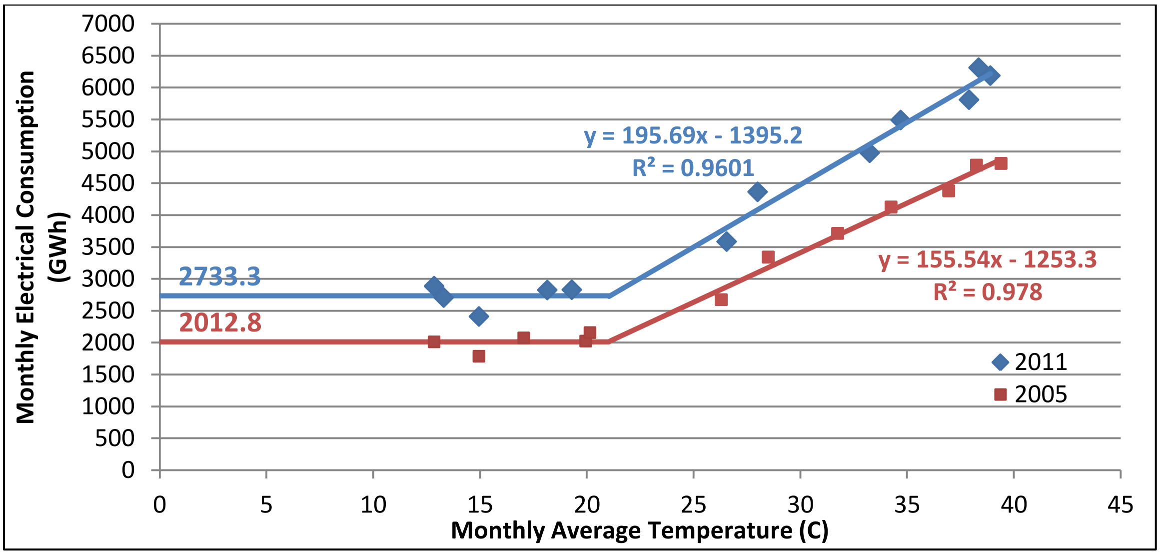


Figure 7: Monthly Electrical Load versus Monthly Average Outdoor Temperature for Kuwait in 2005 and 2011

Several studies have indicated that Heating, Ventilation and Air Conditioning (HVAC) systems in buildings are the largest energy consumers in buildings in the GCC region including Kuwait. Indeed, air-conditioning accounts for almost 60% of the total energy use in a building in most GCC countries (Ventures, 2012). The market for HVAC systems in GCC countries is significant and was estimated at US$ 6.2 billion in 2011 with an annual growth of 3%. Most of the HVAC systems are made up of conventional air conditioning systems including air-handling units, chillers, pumps, and cooling towers. It has been estimated that the installation of energy efficient HVAC systems has the potential to reduce power consumption for air-conditioning by 35 to 40% in the GCC region (Ventures, 2012).

Current Building Energy Efficiency Policies

Minimum requirements for efficient energy use in buildings have been enforced by the Ministry of Electricity and Water (MEW) sector for all new and retrofitted buildings since 1983, through an Energy Conservation Code of Practice which was prepared in accordance with the decision taken by The Council of Ministers in its session 18/80 dated April 20, 1980, that considered the fact that consumers pay only a fraction (5 to 10%) of actual cost of power and energy.

The 1983 energy conservation code of practice specifies minimum thermal resistance for walls and roofs, size and quality for glazing, fresh air requirements, and performance standards for air-conditioning (A/C) systems. More importantly, the code sets the maximum allowable power for the A/C and lighting systems of buildings based on the application, area and type of A/C system. It has been reported that by implementing the code, buildings need 40% less cooling, and more than 40% less peak power and annual energy use. It has also been estimated that implementation of the code, until 2005, resulted in over 2,530 MW savings of peak power, 1.26 million RT of cooling capacity, and nearly 131 million barrels of fuel. The estimated cost of these benefits is well over KD 2.25 billion, in addition to the reduction of over 55 million metric tons of CO_2 in Kuwait's environment (MEW, 2010).

In 2010, a revised version of the energy conservation code of practice has been developed with more stringent requirements for energy efficiency for both new and retrofitted buildings in Kuwait. Table 4 provides a comparative summary of the features of both the recent version of the code of practice for energy conservation completed in 2010 and the original version issued and approved in 1983. As noted in Table 4, the 2010 code of practice has several additional requirements compared to the 1983 version. In particular, the 2010 energy conservation code of practice requires the use of thermal breaks for windows frames, more stringent window sizes and properties, use of programmable thermostats, use of more efficient air conditioning systems, and use of proven technologies such as variable speed drives, cool recovery units, and cool storage systems. Both codes are applicable to new residential and commercial buildings.

The process of the implementation of the code of practice follows several regulations outlined in the following MEW documents:

- MEW/R-1: Regulations for Electrical Installations
- MEW/R-2: Procedures for Approval of Electrical & A/C Drawings and connection of power supply for construction and buildings projects.
- MEW/R-3: Electrical load form and explanatory memo
- MEW/R-4: Regulations for testing of Electrical installations before connection of power supply
- MEW/R-5: General Guidelines for Energy Conservation in buildings
- MEW/R-6: Code of Practice for Energy Conservation in Kuwait building and Appendices
- MEW/R-7: Rules and Regulations for design of A/C System and Equipment
- MEW/R-8: Rules and Regulations for handing over Engineering Services (Electrical and Mechanical) to the Maintenance Authority
- MEW/R-9: General specification for electrical installation

While, Kuwait Municipality inspect that the required thermal insulation levels, window sizes, and glazing types are properly installed, it is the responsibility of the Ministry of Electricity and Water (MEW) to ensure that the electrical and air conditioning systems requirements are met and will not approve the desired electrical power demand for buildings unless they meet the power density limit requirements set by the code of practice. The responsibility of each member of a design team of any new or retrofitted building is briefly summarized below:

1- Architect: ensures that the minimum requirement values for the building envelope components are met (such U-values of exterior walls and roofs, type of glazing for windows, and thermal breaks).
2- Mechanical design engineer: specifies HVAC systems to meet the regulations of the code of practice (outlined in MEW/R-6 and MEW/R-7). The HVAC contractor needs to obtain from MEW, a confirmation that the mechanical systems meet all the required regulations.

3- Electrical design engineer: is responsible to specify electrical systems that comply with MEW regulations (set by MEW/R-1, MEW/R-2, MEW/R-3, and MEW/R-6). The power available for the building is set by MEW and should be obtained by the electrical design engineer before tendering the project.

Table 4: Comparative Summary of the Requirements for Kuwait Energy Conervation Code of Practice of 1983 and 2010

Requirements	Code of Practice 1983	Code of Practice 2010
Design Weather Conditions	Only one set of design weather conditions for all sites in Kuwait	Two sets of design weather conditions are use: interior and coastal sites.
Wall Thermal Insulation	Maximum U-value depending on mass and color levels (Refer to Table A-1 in Appendix A)	Maximum U-value depending on mass and color levels (Refer to Table A-2 in Appendix A)
Roof Thermal Insulation	Maximum U-value depending on mass and color levels (Refer to Table A-1 in Appendix A)	Maximum U-value depending on mass and color levels (Refer to Table A-2 in Appendix A)
Window to Wall Ratio/Glazing type	Maximum WWR value depending on glazing type and orientation (Refer to Table A-1 in Appendix A)	Maximum WWR value depending on glazing type and orientation (Refer to Table A-3 in Appendix A)
Thermal Bridges	Not Mentioned	Columns and beams should be insulated. Windows should have thermal breaks.
Lighting Density		Maximum lighting power density depending on space type (Refer to Table A-4 in Appendix A)
Ventilation Rate	ASHRAE Requirements of Standard 62-1979	ASHRAE Requirements from Standard 62-2001 (Refer to Table A-5 in Appendix A)
Programmable Thermostats	Not Mentioned	Recommended for buildings with part-day occupancy levels with 5°C offset with switching off of air-circulating fans during non-occupancy periods as long as thermal comfort is maintained during occupancy periods.
Motor Efficiency		Minimum efficiency rating depending on motor type and size (Refer to Table 5)
Power Factor		Minimum power factor for motor and fluorescent lighting systems (refer to Table A-6 in Appendix A)
A/C Energy Efficiency	Minimum efficiency for select systems (refer to Table A-1 in Appendix A)	Minimum efficiency rating depending on A/C system type (Refer to Table A-7 in Appenidx A)
Water vs. Air Cooled A/C Systems		Water cooled A/C systems are required for buildings with cooling capacity of 1000 RT or above in the coastal areas and of 500 RT or above for interior areas.
A/C Capacities	Maximum power capacity depending on the building and air conditioning system types	Maximum capacity depending on the building and Air Conditioning System Types (Refer to Table A-4 in Appendix A)
Cooling Recovery Units	Not Mentioned	Required Rotary-wheel cooling recovery units with a minimum efficiency of 75% for all buildings in the coastal areas and for buildings with high ventilation needs (940 L/s or 2000 cfm or above) in the interior areas. Exceptions apply for health reasons
Variable Speed Drives	Not Mentioned	Required for fan motors of cooling towers
Cool Storage Systems	Not Mentioned	Required for buildings with part-day occupancy and more than 100 RT cooling peak load
District Cooling	Not Mentioned	Recommended based on cost analysis for large complexes such as university campuses and residential neighborhood.
Seawater use for condensers	Not Mentioned	Recommended for water-cooled plants of more than 5000 RT capacity in coastal areas

Potential of Energy Efficiency in Buildings

Few published studies have considered the potential of improving the energy efficiency of buildings in Kuwait. The following sections provide a brief review of the literature for improving the energy performance of both new and existing Kuwaiti buildings. First, the potential of energy efficiency for commercial buildings is discussed. Then, the results reported for the potential to reduce the energy consumption in residential buildings are outlined.

Potential for Commercial Buildings

Al-Anzi (2007) conducted a survey of 9 commercial buildings in Kuwait City to assess their energy use intensity. The results of the survey are summarized in Table 5. The conditioned area of these buildings ranged from about 12,000 m^2 to 46,000 m^2, while the energy use ranged between 232 $kWh/m^2/yr$ and 632 $kWh/m^2/yr$. More than 2/3 of the surveyed buildings have energy consumption above 400 $kWh/m^2/yr$. This energy use intensity is larger than that reported for other countries. For example, in the US the consumption of a typical high-rise office building is around 375 $kWh/m^2/Yr$ (Todesco, 1996), while in Australia it is about 254 $kWh/m^2/yr$ (COAG, 2012), and in Hong Kong it is about 292 KWh/m^2 (Lam et al., 2008).

Table 5: General Characteristics and Annual Energy Use of Office Buildings in Kuwait

No.	Building Type	Number of Floors	Conditioned Floor Area (m^2)	Cooling Capacity (Tons)	Annual Electrical Energy Use (kWh)	Energy Use per Floor Area (kWh/m^2)
1	Office Building - Government	24	33,000	1,368	13,992,000	424
2	Mutli-Use Building - Private	19	29,519	1,100	8,649,067	293
3	Office Building - Private	12	16,855	450	4,230,605	251
4	Bank Headquarters - Private	10	22,695	1,030	5,310,630	234
5	Bank Headquarters - Private	32	13,310	438	8,411,920	632
6	Office Building - Private	20	11,545	450	4,652,635	403
7	Office Building - Government	10	31,267	750	13,507,344	432
8	Office Building - Government	6	13,238	420	5,348,152	404
9	Office Building - Private	18	46,230	1,300	17,197,560	372

Moreover, Krarti and Hajiah (2011) have found through combination of energy auditing and whole-building energy simulation of a wide range of buildings that electricity peak demand and annual energy use associated to air-conditioning of commercial buildings are significant in Kuwait. Figure 8 illustrates the end-use distribution of respectively the electrical peak demand and annual electricity consumption for a typical office building in Kuwait (Krarti and Hajiah, 2011). As clearly indicated in Figure 8, air-conditioning represents a significant portion of both annual electrical energy use and electricity peak demand for the prototypical office building with a fraction of 26%, and 38% respectively without accounting for fans and pumps.

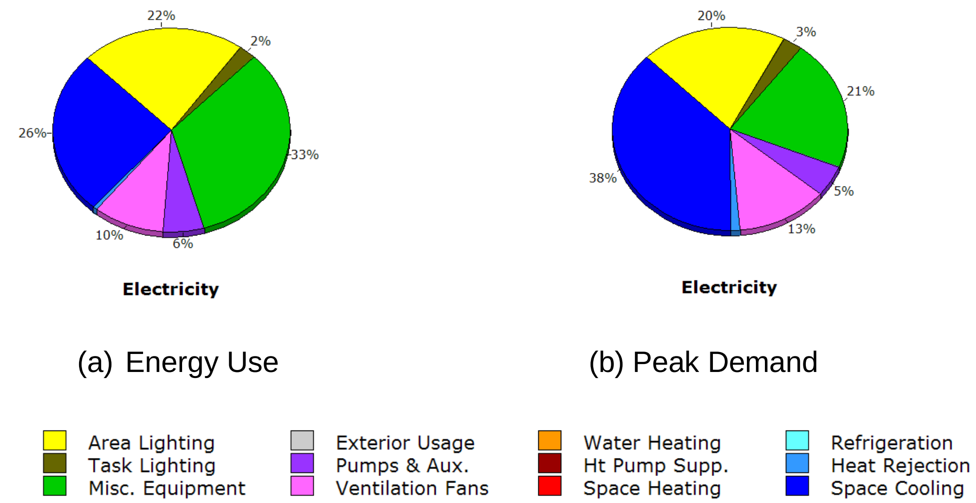


Figure 8: End-Use Distribution for a Kuwaiti Office Building Associated with (a) Annual Electricity Energy Consumption and (b) Electricity Peak Deamnd (Source: Krarti and Hajiah, 2011)

One of the first attempts to reduce energy use in existing Kuwaiti buildings has been reported by Al-Ragom (2002) through energy auditing of a governmental office building with 23,470 m^2 of air-conditioned floor area. By using free cooling during the winter (economizer cycle) and reducing the operation of the air-conditioning system during the non-occupied hours as well as turning off lighting during non-occupancy hours and de-lamping, it is estimated that 26% savings can be achieved in annual energy consumption.

More recently, Al-Mulla et al. (2013) have described the results of implementing three simple enhanced operating strategies in eight governmental buildings with a total combined air conditioned floor area of 439000 m^2 and peak demand of 29.3 MW. The enhanced operating strategies include:

1. Reduction of cooling supply during one hour before the occupancy period (i.e., between 13:00 and 14:00 during week days) by limiting the operation of chillers and air distribution systems.
2. Improved controls after occupancy period with changing the temperature settings and air flow rates as well as turning off any non-essential lighting fixtures.
3. De-lamping of spaces where excess illumination levels are observed within the buildings including corridors, lobbies, and parking lots.

In all buildings, peak demand and energy use savings have been achieved based on data obtained before and after implementation of the enhanced operating strategies through monitoring of hourly energy consumption during several days during one summer season. About 8.90 MW (or 30%) in combined peak demand was saved for all buildings. Daily energy savings ranging from 3.2% to 13.0% were achieved using rather easy to implement operating strategies from all the buildings without significantly affecting the indoor thermal comfort.

Similar enhanced operating strategies have been implemented in a large shopping mall (about 170,000 m^2 of space) in Kuwait by Al-Hadban et al. (2010). Before the implementation of the improved controls, the shopping mall consumes 84,000 MWh/yr with a peak demand of 15 MW. After the implementation of the enhanced operation strategies, it is estimated that the annual savings in energy use is 9,919 MWh/yr (or 11.8% savings) and a reduction in peak demand of 345 kW (or 2.3% savings).

A study by Al-Ajmi (2012) showed that non-retrofitting energy conservation measures (ECMs) with no or low capital investment only saved 6.5% of an educational building annual energy consumption, while the retrofitting ECMs with significant capital investment can save up to 49.3% of annual energy consumption.

Potential for Residential Buildings

As noted in Figure 5, residential buildings account for a significant portion of electricity consumption in Kuwait. Through combination of energy auditing and whole-building energy simulation analysis, Krarti and Hajiah (2011) estimated the end-use of electricity peak demand and annual energy consumption associated to a typical residence in Kuwait as illustrated in Figure 9. As clearly shown in Figure 9, air-conditioning represents a significant portion of both annual energy consumption and electricity peak demand for both the villa and the office building with a fraction of 48%, and 64%, respectively without accounting for fans and pumps.

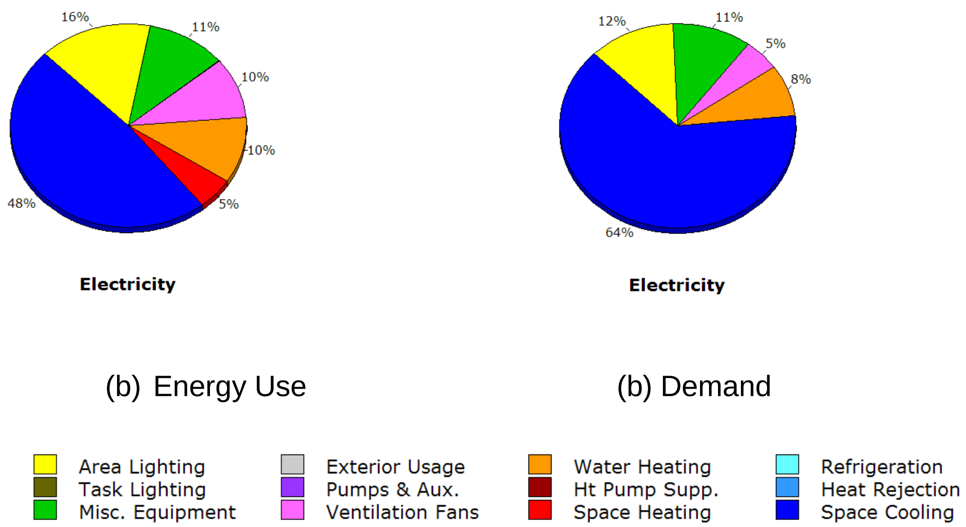


Figure 9: End-USe Distribution for a Kuwaiti Residence Associated with (a) Annual Electricity Energy Consumption and (b) Electricity Peak Demand (Source: Krarti and Hajiah, 2011)

Using simulation analysis for 2-story residential building, Al-Ragom (2003) has found that the use of wall and roof insulation and reflective double glass with reduced window area (so that the window-to-wall ratio is 10%) can decrease the annual energy consumption for a residence to 293 kWh/m^2 in Kuwait which is characterized by a hot and arid climate. Compared to a base case model with no insulation in the walls and roof and with single clear glazing and 23.5% window-to-wall ratio, annual energy use savings of 250 kWh/m^2 or 46% can be achieved using basic envelope energy efficiency measures. The study also found that:

- As a result of the highly subsidized electricity rates, as expected, the customer payback periods were very long. Even for the best case of energy saving, the payback period was 37 years. With such long periods, it is very difficult to justify implementation of retrofitting schemes by homeowners. For this reason, alternative pricing policies for electricity were investigated to yield an acceptable payback period.
- In order for retrofitting to be considered feasible, customers have to be charged at a rate that is at least 650% higher than the current price, which is 0.6 cents/kWh (2 fils/kWh).
- Another financing option was examined in which the government pays the full amount of the retrofitting cost. With this option, it was found that the payback period for the

government varied from 5 to 16 years, and it was 6 years for the most energy efficient option.

- The highly subsidized cost of electricity imposes a burden on the government budget. If the government would seriously consider retrofitting all old residential buildings, the initial cost of retrofitting can be recovered in 6 years. After the sixth year, savings in energy consumption will provide annual national revenue of $136.26 million (42.27 million KD). In 10 years, the savings of $577 million (179 million KD) can be realized for the government. This amount accounts for the total cost of retrofitting that is fully borne by the government. In addition, the peak electric load reductions due to retrofitting those buildings would save 636 MW of electric power requirement, which is 8% of the installed national capacity

A recent study by Krarti and Ihm (2014) has indicated the potential of using proven energy efficiency measures to reduce the energy consumption of homes in various MENA countries. In the analysis, a sequential search optimization technique coupled with detailed energy simulation program are utilized to evaluate the most cost-effective energy efficiency measures that should be implemented for a prototypical residential building located in various sites within the MENA region. In the optimization analysis, a wide range of energy efficiency measures (EEMs) are considered including orientation, window location and size, glazing type, wall and roof insulation levels, lighting fixtures, temperature settings, and efficiencies of heating and cooling systems. A brief discussion of the options associated with each EEM is provided below:

- Orientation defined by the azimuth angle between the true south and the front of the house. Seven options for the orientation are considered varying from 0^o (baseline) to 270^o.
- Exterior wall and roof insulation defined by the thickness of polystyrene insulation. Four options are considered with a no insulation (R-value = 0) to 6-cm insulation (R-value = 3.0 $W/m^2.K$).
- Window size defined by the window-to-wall ratio (WWR). Four options are evaluated ranging from small windows (WWR=10%) to large windows (WWR=40%). The window to wall ratio (WWR) of the baseline building model is 25%.
- Glazing type characterized by the number of panes and the coating type applied to the glazing surfaces. Six glazing types are considered in the analysis.
- Lighting type defined by the lighting power density. Four lighting options are considered including (i) all fixtures are incandescent lamps (baseline with 7.3 W/m^2), (ii) 1/3 of the fixtures are compact fluorescent lamps (CFLs) while the other remain incandescent lamps (i.e., 30% reduction in baseline lighting power density), (iii) 2/3 of the fixtures are CFLs while the other remain incandescent lamps (i.e., 50% reduction in baseline lighting power density), and (iv) all the fixtures are CFLs (i.e., 70% reduction in baseline lighting power density).
- Air leakage level defined by the air infiltration rate. Four levels are considered: leaky (baseline with an infiltration rate of 0.7 $L/s/m^2$), moderate leakage level with 25% reduction in baseline infiltration rate, good leakage level with 50% reduction in baseline infiltration rate, and tight level with 75% reduction in baseline infiltration rate.
- Cooling temperature setting defined by the maximum acceptable indoor temperature needed to maintain thermal comfort. Three temperature settings are evaluated 24^oC, 25^oC, and 26^oC.
- Refrigerator energy efficiency level defined by its class label. Four options are considered: baseline with an annual use consumption of 800 kWh/year, refrigerator of class 3 with 30% reduction in baseline annual energy consumption, refrigerator of class 2 with 45% reduction in baseline annual energy consumption, and refrigerator of class 1 with 65% reduction in baseline annual energy consumption.

- Boiler type defined by its energy efficiency level. Four energy efficiency levels are considered: 80% (baseline with low-efficiency), 85% (standard efficiency), and 90% (high efficiency), and 95% (premium efficiency consisting of a condensing boiler).
- Cooling system type defined by its coefficient of performance or COP level. Four COP levels are considered: COP=2.6 (baseline with low-efficiency), COP=3.0 (standard efficiency), and COP=3.3 (high efficiency), and COP=3.5 (premium efficiency).

Figure 10 shows diagrams illustrating the optimal paths to design energy efficient residential buildings in five cities representative of climate features for GCC countries including Kuwait. It should be noted that the economic analysis (LCC) performed to obtain the optimization results of Figure 10 utilizes non-subsidized electricity generation costs. Appendix B provides additional results of the same study to illustrate the impact of both electricity prices and EEM implementation costs. As illustrated in Figure 10, optimal source energy savings for all the five cities ranging from 38% to 62% can be achieved while minimizing LCC values. Kuwait has the highest potential for energy use savings (62%). Table 6 lists the optimal package of EEMs and the initial costs that provide the minimal LCC value for all the five GCC locations considered in the analysis.

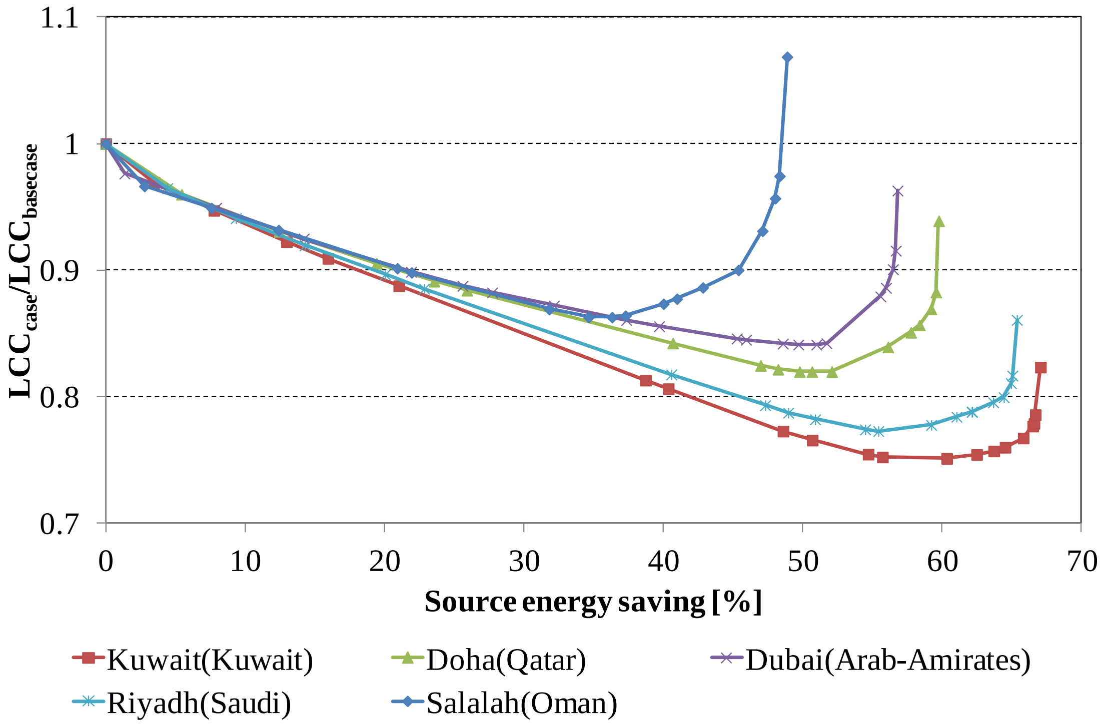


Figure 10: Life Cycle Cost Relative Ratio as a Function of Source Energy Savings for a Residence Located in Five Selected GCC Cities

Table 6: List of EEMs for the Optimal LCC Case and Associated Initiated Costs and Annual Energy Use Savings

Site, Country	List of EEM for Optimal LCC Package	Initial Costs for all EEMs ($)	Annual Electrical Energy Use Savings [kWh, (%)]
Kuwait City, Kuwait	2-cm Polystyrene Insulation in Walls and Roof; Tinted Bronze Glazing, CFL/LED lighting,	$15,005	97,047 kWh (62%)

	Low air leakage, Premium efficiency AC (COP=3.3), Cooling Set Point = 26°C		
Riyadh (KSA)	2-cm Polystyrene Insulation in Walls and Roof; Tinted Bronze Glazing, CFL/LED lighting, Low air leakage, Premium efficiency AC (COP=3.3), Cooling Set Point = 26°C	$15,005	82,391 kWh (58%)
Doha (Qatar)	Tinted Bronze Glazing, CFL/LED lighting, Low air leakage, Premium efficiency AC (COP=3.3), Cooling Set Point = 26°C	$14,166	62,525 (54%)
Dubai (UAE)	2-cm Polystyrene Insulation Roof; Tinted Bronze Glazing, CFL/LED lighting, Low air leakage, Standard efficiency AC (COP=3.0), Cooling Set Point = 26°C	$14,310	56,583 (53%)
Salalah (Oman)	CFL/LED lighting, Standard efficiency AC (COP=3.0), Cooling Set Point = 26°C	$12,715	30,592 (38%)

Assessment Analysis Methodology

While Kuwait was the first MENA country to develop and implement energy efficiency code for buildings in 1983, it took over 23 years to revise the energy conservation code of practice in 2010. Thus, a significant fraction of the existing building stock in Kuwait complies with the requirements of 1983 Energy Conservation code of practice. The application of the 2010 energy conservation code of practice has been rather slow and will most likely take some time before it is fully implemented in the new and retrofitted buildings.

In this section, an analysis is carried out to determine the impact of retrofitting existing Kuwaiti building stock to meet the 2010 energy conservation code of practice expressed in terms of savings in energy use and peak demand, and CO_2 emissions savings. The analysis approach for residential buildings considered in this section is based on the work of Ameer and Krarti (2014).

<u>Analysis Approach:</u>
A whole building simulation analysis tool (i.e., eQUEST) is utilized to model an existing house in Kuwait. Figure 11 shows renderings of the house model that is considered in this analysis. The house has 501 m^2 (5390 ft^2) of total floor area that is fully air-conditioned. In order to estimate energy consumption for the house, schedules that outline people behavior, lighting systems, and equipment operation are based primarily on survey data obtained for 30 Kuwaiti families conducted by Al-Mumin (2003).

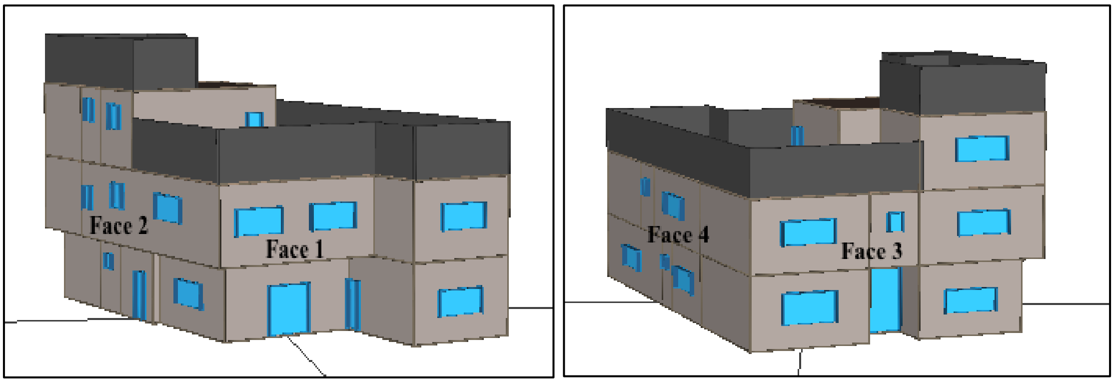


Figure 11: Rendering for the Existing Kuwaiti House Energy Model Used in the Simulation Analysis

The building characteristics of the house energy model are summarized in Table 7 for various configurations including, base case (as built), worst case (no insulation is used), code-1983 (meets the 1983 code of practice), code-2010 (meets the 2010 code of practice) with two cases (case A: without any fences or neighboring buildings, and case B: with both the fences and the neighboring buildings).

Table 7: Main Characteristics for 5 House Energy Models Considered in the Analysis

Item	Base Case	Worst Case (Unisulated)	Code-1983	Code-2010 Case (A)	Code-2010 Case (B)
Ext. Wall	U = 0.551 ($W/m^2.K$)	U = 2.305 ($W/m^2.K$)	U = 0.568 ($W/m^2.K$)	U = 0.568 ($W/m^2.K$)	U = 0.568 ($W/m^2.K$)
Ext. Roof	U = 0.693 ($W/m^2.K$)	U = 0.693 ($W/m^2.K$)	U = 0.397 ($W/m^2.K$)	U = 0.397 ($W/m^2.K$)	U = 0.397 ($W/m^2.K$)
Window type	Single reflective	Single clear	Double clear	Double reflective	Double reflective
Window over hang and fins	0.25 m over hang and fins	No overhang and fins	No overhang and fins	No overhang and fins	0.25 m overhang and fins
Minimum outside air ventilation	0	0	0	According to Table A-5	According to Table A-5
Cooling COP	2	2	2	2.3	2.3
Lighting power density	9.7 W/m^2	9.7 W/m^2	15.07 W/m^2	9.7 W/m^2	9.7 W/m^2
Fence Wall	2.50 m high fence walls in all direction	No fence walls	No fence walls	No fence walls	2.50 m height
Neighbors	Two neighbors with 7.9 m height in front of faces 2 & 4	No neighbors	No neighbors	No neighbors	Two neighbors with 7.9 m height in front of faces 2 & 4

Moreover, the simulation analysis includes the impact of several energy efficiency measures (EEMs) on the annual energy consumption of the house such as glazing type, windows size, temperature settings, and COP of the air conditioning system. Figure 12 shows the EEMs considered as well as their impact in reducing the energy use of the house. The improvement of the efficiency of the air conditioning system has the highest impact with a potential to reduce the annual electricity consumption for the house by up to 41% (Ameer and Krarti, 2014).

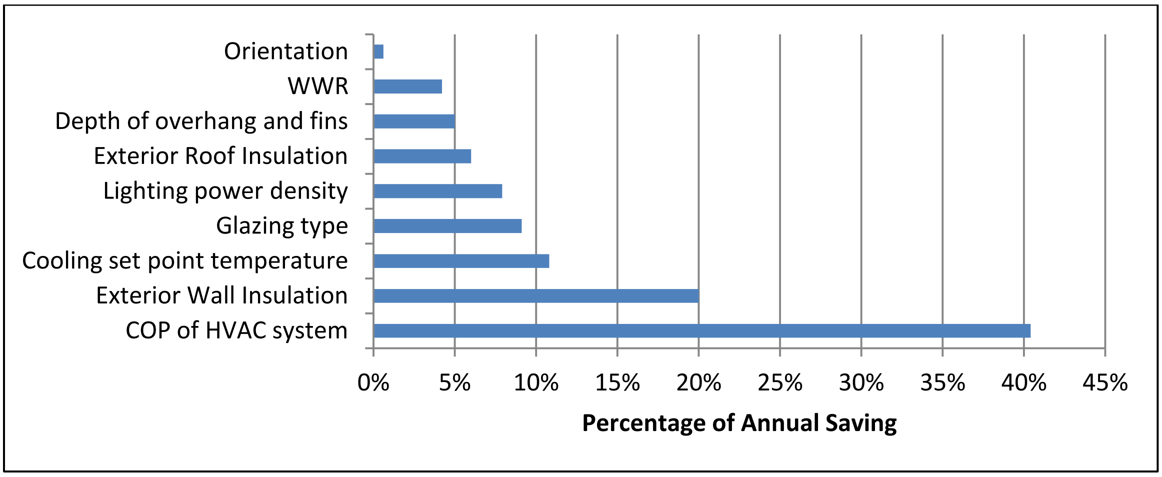


Figure 12: Maximum Percent Savings in Annual Energy Consumption for Some Energy Efficiency Measures Applied to an Existing House in Kuwait

While the analysis presented in this report is conducted using one residential building, its results can be extrapolated for a portion or all the existing residential building stock using the 2011 statistics developed and published by MEW (2012). A similar approach can be carried out for the commercial buildings. The number as well as the energy consumption and peak demand of residential and commercial buildings are provided in Table 8 and are obtained based on 2011 MEW statistics in Table 3 and Figure 5 (MEW, 2012).

Table 8: Number, Annual Energy Use, and Peak Demand for all Building Types Considered in the Analysis

Building Type	Number of Units	Annual Energy Use (GWh)	Demand Peak (MW)
Private Residential	390213	9228	5273.4
Governmental Residential	1448	1964	1122
Commercial	45685	3534	2019.6
Governmental	7553	3142	1795.2
Total	34361	19635	11220

The economical and environmental analyses presented in this report are based on the following assumptions:

- Electricity in Kuwait is charged at 2 fils/kWh, which is a fraction of the 38 fils/kWh it costs to produce (Capital Standards, 2013). The economic analysis utilizes the 38 fils/kWh (0.134/Wh) electricity rate.
- The cost of installing of power plant is estimated at $1200/kW (Al-Mulla et al., 2013).
- The carbon generation intensity for Kuwait is 870 gCO_2/KWh (IEA, 2012)

Economic, Environmental, and Policy Analysis

In this section, a summary of a comprehensive analysis is presented to assess the economical and environmental impacts from a national program to improve the energy efficiency of not only new buildings but of the existing building stock in Kuwait. The same analysis is utilized to evaluate the benefits for implementing 2010 version of the energy conservation code of practice instead of the 1983 version for new buildings. As will be discussed in this section, significant benefits can be achieved by implementing a national energy efficiency program for existing buildings in Kuwait. This program can offer an alternative policy option to the elimination or a reduction of the significant energy subsidies that render any energy retrofits not cost-effective for the end-users.

Energy Savings Analysis

Figure 13 illustrates the impact of the energy conservation code on the annual energy use for a Kuwaiti house model illustrated in Figure 11. In particular, it shows that the application of 1983 version of the code of practice (code-1983 case) can save 11% of the annual energy consumption when the house has no insulation for exterior walls and roof and utilizes single pane windows (worse case design). However, the application of the 2010 version of the code of practice (code-2010 case B) leads to 32% savings relative to the worse case design. It is interesting to note that the existing house configuration (base case) performs better than the code-1983 case due mainly to better lighting systems and the presence of neighboring buildings to provide additional shading as detailed in Table 7.

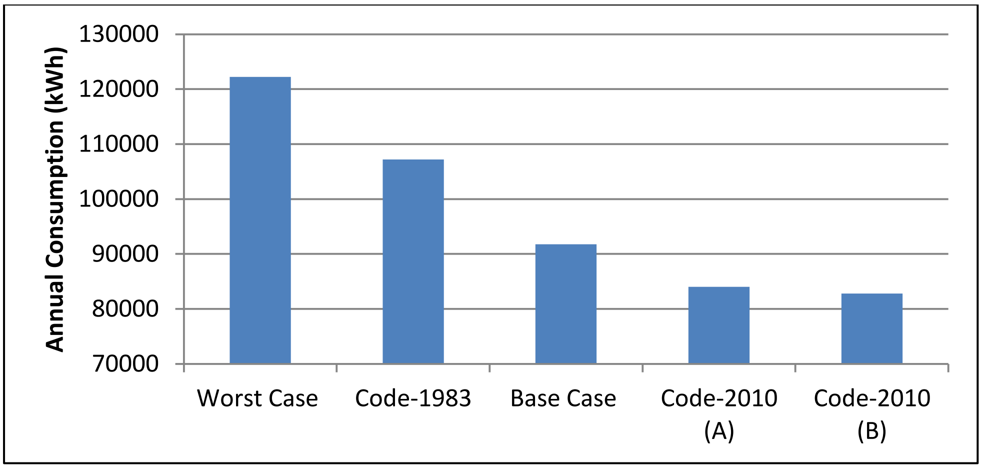


Figure 13: Annual Electrical Consumption for Five House Design Configurations

The potential annual energy use savings that can be achieved when an exsiting house (base case) is retrofitted to the 2010 energy conservation code of practice level are about 8% as shown in Figure 14. However, these savings increase to 23% when a house built using the 1983-code design specifications is retrofitted to the 2010-code design requirements through installing more energy efficient lighting system, glazing, and air conditioning system.

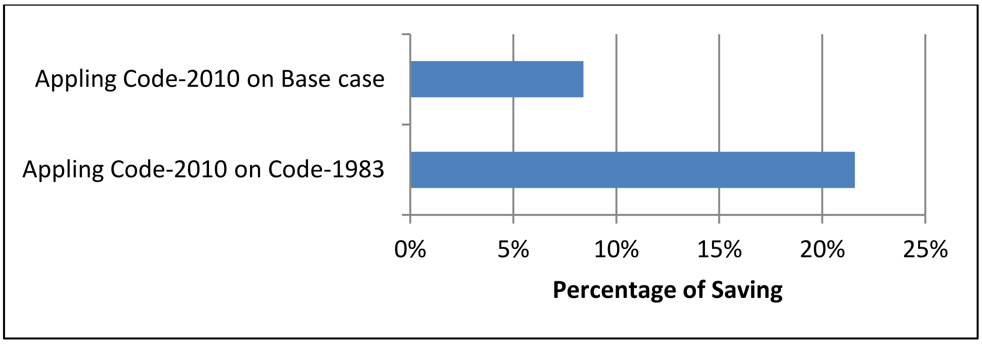


Figure 14: Annual Electrical Consumption Percent Savings by Applying Code 2010 on Code 1983 and Base-case House Configurations

Based on the analysis briefly outlined above and the available literature on potential energy use savings that can be achieved from retrofitting existing buildings in Kuwait (refer to the section entitled Potential Energy Efficiency in Buildings), it is highly recommended that MEW sets a national program to upgrade the energy efficiency for the existing building stock in Kuwait while continuing to require that any new building should be constructed to at least comply with the 2010 version of energy conservation code practice while working to establish more stringent regulations.

Three levels of energy efficiency building retrofit program are suggested for Kuwait with different levels of economical and environmental benefits:

- ***Level-1 of energy efficiency retrofit:*** in this case, the buildings are required to undergo basic or level-1 energy audit followed by implementing low-cost energy efficiency measures such installation of programmable thermostat, use of CLF or LED lighting, and weatherization of building shell to reduce air infiltration. The estimated savings from a level-1 retrofit program can range from 4% to 12% for all building types based on documented case studies for residential, commercial, and governmental buildings. In this analysis, average savings of 8% are considered for level-1 energy efficiency retrofits.

- ***Level-2 of energy efficiency retrofit:*** a standard or level-2 energy audit is required for this program in order to improve the building envelope components to meet at least 2010 energy conservation code of practice requirements as well as use of energy efficient cooling systems and appliances. Based on the analysis shown in Figure 13 as well as the exiting literature, average savings of 23% can be achieved for level-2 retrofit programs for all building types.

- ***Level-3 of energy efficiency retrofit:*** for this program, detailed or level-3 energy audit is required to perform deep retrofit of the buildings. A wide range of energy efficiency measures can be considered in this type of program including window replacement, cooling system replacement, use of variable speed drives, and installation of daylighting control systems. While, deep retrofits are typically costly, they can provide significant savings exceeding 50% as noted in the study of Ihm and Krarti (2014).

Economical and Environmental Analysis

In this section, the economical and environmental benefits for the building energy efficiency retrofit program is assessed for residential, commercial, and governmental buildings using MEW statistics of 2011 for the building stock in Kuwait (MEW, 2012). The economical benefits are estimated using the cost of 38 fils/kWh for generating and distributing electricity (i.e., \$0.134/kWh) rather than the subsidized rate of 2 fils/kWh (i.e., \$0.006/KWh). The environmental benefits are estimated using the carbon emissions of 870 gCO_2/kWh for Kuwait. Tables 9, 10, and 11 summarize the annual CO_2 emissions savings (associated with reducing the amount of fuel needed to generate electricity), annual energy cost savings (associated with using less fuel to generate electricity), and the peak demand savings (associated with avoiding constructing new power plants) for respectively, Level-1, Level-2, and Level-3 building energy efficiency retrofit programs in Kuwait for various building types. As clearly shown in Tables 9-11, significant economical and environmental benefits can be achieved for all the levels of the retrofit programs. Higher benefits can be achieved for Level-2 and Level-3 programs compared to Level-1. However, these programs require higher investments as will be discussed in the Cost-Effectiveness Analysis section. The benefits are significantly higher for the residential buildings than for commercial or governmental buildings for any retrofit level. Indeed, 50% of the benefits can be achieved by solely retrofitting the residential buildings in Kuwait.

Table 9: Economical and Environmental Benefits for Level-1 Building Energy Efficiency retrofit Program for Kuwait Based on 2011 Building Stock Statistics

Building Type	Annual Energy Use Savings (GWh/yr)	Peak Demand Savings (MW)	Annual CO_2 Emissions Savings (10^3 Tons/yr)	Annual Energy Cost Savings ($ Million/yr)	Peak Demand Savings ($ Million)
Private Residential	738	422	642	99	506
Governmental Residential	157	90	137	21	108
Commercial	283	162	246	38	194
Governmental	251	144	219	34	172
Total	1429	817	1244	192	980

Table 10: Economical and Environmental Benefits for Level-2 Building Energy Efficiency Retrofit Program for Kuwait Based on 2011 Building Stock Statistics

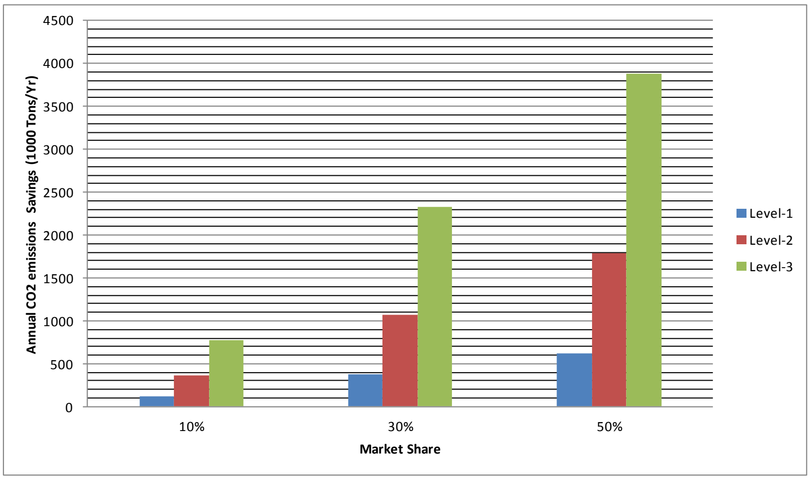
Building Type	Annual Energy Use Savings (GWh/yr)	Peak Demand Savings (MW)	Annual CO_2 Emissions Savings (10^3 Tons/yr)	Annual Energy Cost Savings ($ Million/yr)	Peak Demand Savings ($ Million)
Private Residential	2123	1213	1847	286	1455
Governmental Residential	452	258	393	61	310
Commercial	813	465	707	109	557
Governmental	723	413	629	97	495
Total	4110	2348	3575	553	2818

Table 11: Economical and Environmental Benefits for Level-3 Building Energy Efficiency Retrofit Program for Kuwait Based on 2011 Building Stock Statistics

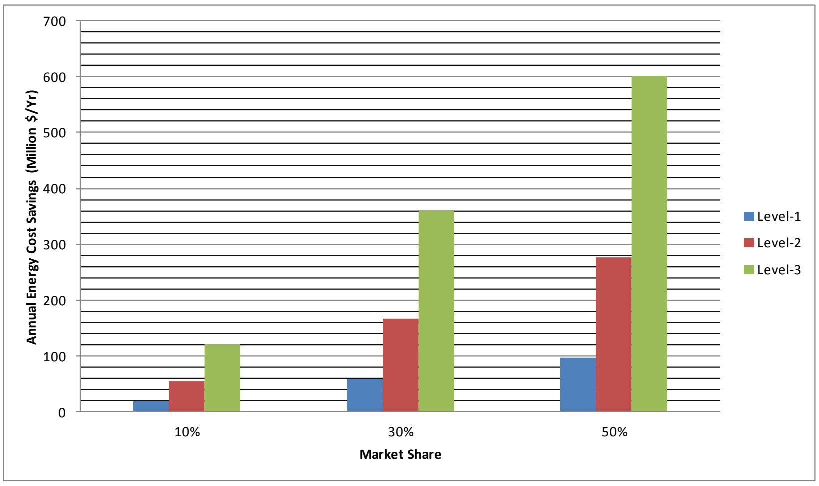
Building Type	Annual	Peak	Annual CO_2	Annual	Peak

	Energy Use Savings (GWh/yr)	Demand Savings (MW)	Emissions Savings (10^3 Tons/yr)	Energy Cost Savings ($ Million/yr)	Demand Savings ($ Million)
Private Residential	4614	2637	4014	621	3164
Governmental Residential	982	561	854	132	673
Commercial	1767	1010	1537	238	1212
Governmental	1571	898	1367	211	1077
Total	8934	5105	7773	1202	6126

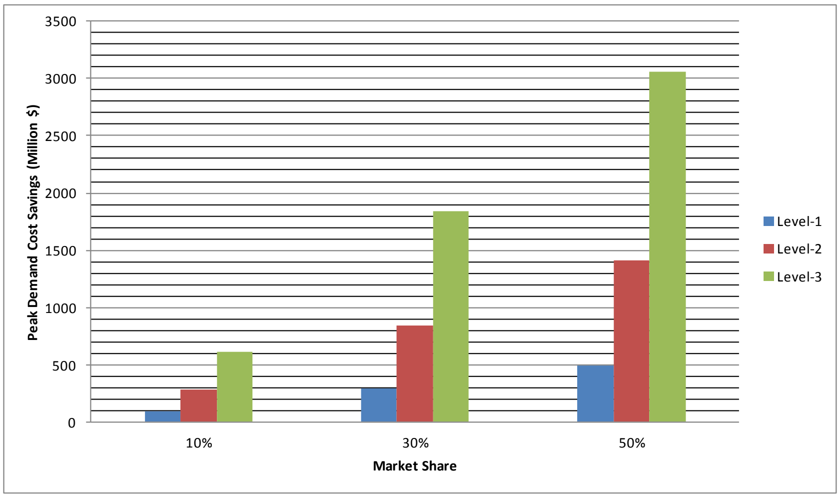
It is expected that the implementation of the proposed building energy efficiency retrofit program to be gradual and to require several years for implementation due to the needed investments (refer to the Cost-Effectiveness Analysis section), and the lack of qualified energy efficiency contractors in Kuwait. However, the retrofit program can lead to significant economical and environmental benefits for Kuwait even if only a small fraction of the existing stock is targeted. Figure 15 illustrates the effect of market share (fraction of the building considered among the entire existing building stock) for implementing any level of the building energy efficiency retrofit program on annual savings of carbon emissions [i.e., Figure 15(a)], annual savings of annual energy costs [i.e., Figure 15(b)], and savings of peak demand costs [i.e., Figure 15(c)]. The benefits remain significant especially for retrofitting the existing residential buildings.



(a) Annual CO_2 Emissions Savings



(b) Annual Energy Cost Savings



(c) Peak Demand Savings

Figure 15: Impact of Market Share on the Economical and Environmental Benefits of the Building Energy Efficiency Retrofit Program

It should be noted that over the last decade, the number of buildings in Kuwait has increased at an average annual rate of 4% mostly attributed to new buildings (MEW). Based on the existing building stock in 2011, the application of the 2010 instead of 1983 version of the energy conservation code of practice to only new buildings would lead to the following benefits (that can be estimated from Figures 12-14 with a market share of 4% associated to Level-2 energy efficiency retrofit program):

- 164 GWh/year in annual energy savings
- 94 MW in peak demand reduction
- 143 10^3 metric tons/year in annual reduction of CO_2 emissions

While these benefits are substantial, they are not significant when compared to the benefits associated with the retrofit of the entire existing building stock or even solely the existing privately owned residential buildings in Kuwait. In the next section, the implementation and the cost-effectiveness of mandatory national energy efficiency retrofit program for the entire Kuwaiti building stock is discussed.

Policy Design Considerations

In this section, first the costs needed to fully implement the building energy efficiency retrofit program are evaluated. In this analysis, the particular costs attributed to updating the Kuwait buildings to meet the energy savings potential set by the 2010 energy conservation code of practice are estimated. Then, the cost-effectiveness of energy efficiency program is determined for various building types and levels of energy efficiency retrofit. The job creation potential associated with the energy efficiency retrofit program is also discussed in this section.

Cost-Effectiveness Analysis

In order to assess the required investments needed to implement any of the three levels of building energy efficiency retrofit program, a cost-effectiveness analysis is carried out. It should be noted that these investments can be provided by the government of Kuwait at least in the first phase of implementation (for instance to jump start level-1 program for the first 10% of the residential buildings). Several techniques are now available to determine the best buildings for energy retrofits (Krarti, 2012). Other alternatives exist to implement the retrofit program including providing incentives and grants for energy retrofits while gradually eliminating energy subsidies. As noted in Figure 3, Kuwaiti government is currently providing about $3729 per person in energy subsidies. As discussed later, this amount is sufficient to perform Level-1 and even Level-2 energy retrofit for most residences in Kuwait. Instead of subsidies, the Kuwaiti government can provide in the form of grants of $1,000 or $5,000 for each homeowner to perform Level-1 or Level-2 energy retrofit.

The cost of the implementation for each level of building energy retrofit depends on several factors including the building size and the physical conditions of the building energy systems. Based on various sources including cost of labor and materials in Kuwait, the average costs of completing energy retrofit for buildings are estimated (Krarti, 2011; Ihm and Krarti, 2014; and Ameer and Krarti, 2014). Table 12 summarizes these costs of implementation for any of the three level of energy retrofit specific to residential, commercial, and governmental buildings including costs for performing energy audits as well as for installing suitable energy efficiency measures.

Table 12: Average Costs for Energy Retrofits of Buildings in Kuwait (in US Dollars)

Building Type	Level-1	Level-2	Level-3
Private Residential	$500	$5,000	$10000
Governmental Residential	$500	$5,000	$10000
Commercial	$10,000	$50,000	$100000
Governmental	$30,000	$150,000	$300000

The total costs of implementation for each level of the building energy efficiency retrofit program to upgrade the existing building stock in Kuwait are provided in Table 13 (for Level-1), Table 14 (Level-2), and Table 15 (for Level-3). To retrofit the entire building stock, investments of $879 Millions, $5376 Millions, and $10571 Millions are required for respectively, Level-1, Level-2, and Level-3 of building energy efficiency retrofit program. While these amounts seem significant, the program is very cost-effective as noted in Table 16 for the entire building stock and Table 17 for only the private residential buildings. In fact, Level-1 retrofit program does not effectively require any investments since it provides sufficient savings from the reduction in electricity peak demand to avoid investing in additional power plants. For the residential buildings, Level-2 and Level-3 retrofit programs have a payback of 1.7 years and 1.2 years, respectively.

Table 13: Total Implementation Costs for Level-1 Building Energy Efficiency Retrofit Program

Building Type	Number of Units	Per Unit Retrofit Cost ($/Unit)	Total Retrofit Cost (Million $)
Private Residential	390,213	500	195
Governmental Residential	1,448	500	1
Commercial	45,685	10,000	457
Governmental	7,553	30,000	227
Total	444,899		879

Table 14: Total Implementation Costs for Level-2 Building Energy Efficiency Retrofit Program

Building Type	Number of Units	Per Unit Retrofit Cost ($/Unit)	Total Retrofit Cost (Million $)
Private Residential	390,213	5,000	1951
Governmental Residential	1,448	5,000	7
Commercial	45,685	50,000	2284
Governmental	7,553	150,000	1133
Total	444,899		5,376

Table 15: Total Implementation Costs for Level-3 Building Energy Efficiency Retrofit Program

Building Type	Number of Units	Per Unit Retrofit Cost ($/Unit)	Total Retrofit Cost (Million $)
Private Residential	390,213	10000	3902
Governmental Residential	1,448	10000	14
Commercial	45,685	100000	4569
Governmental	7,553	300000	2266
Total	444,899		10,751

Table 16: Cost-Effectiveness of Energy Efficiency Retrofit Programs for all Kuwaiti Building Stock

Retrofit Level	Total Retrofit Cost (Million $)	Peak Demand Savings (Million $)	Annual Energy Cost Savings (Million $/yr)	Simple Payback Analysis (Yrs)
Level-1	879	980	192	**0**
Level-2	5,376	2,818	553	**4.6**

Level-3	10,751	6,126	1202	**3.8**

Table 17: Cost-Effectiveness of Energy Efficiency Retrofit Programs for only Private Residential Buildings in Kuwait

Retrofit Level	Total Retrofit Cost (Million $)	Peak Demand Savings (Million $)	Annual Energy Cost Savings (Million $/yr)	Simple Payback Analysis (Yrs)
Level-1	195	506	99	**0**
Level-2	1,951	1,455	286	**1.7**
Level-3	3,902	3,164	621	**1.2**

Job Creation Analysis

The other economical impact of the building energy efficiency retrofit program is the potential to create new jobs in Kuwait. Indeed, a study by Rockefeller Foundation (2012) has indicated that retrofit of existing buildings including replacing and upgrading energy consuming systems offer an important investment opportunity with significant economic and environmental impacts including high employment potential. Specifically, the study has found that $279 billion can be invested in retrofitting US residential, commercial, and institutional buildings with savings in energy costs of $1 trillion over 10 years (i.e., with an average payback period of less than 4 years) resulting in annual reduction by 30% in US electricity expenditures. When all the retrofits are undertaken, about 3.3 million jobs can be created throughout the US with the vast majority related to improve the energy efficiency of residential buildings. The job creation model used is based on a study by Pollin et al. (2009) which utilized survey data to estimate the number of direct and indirect full time job years that can be created by $1.0 million expenditures in the energy sector as outlined in Table 18 for various energy sources. For building retrofits, the direct effects consist of jobs created to implement the energy efficiency measures while the indirect effects are associated with the jobs needed to produce and supply energy efficiency equipment and materials. It should be noted that there are induced job creation associated with the direct and indirect effects, that is, the expansion of employment as the result of spending earnings from people who have acquired direct or indirect jobs. For the energy sector, it was found that the level of induced job-year creation is 40% of the level for direct and indirect job-year creation. Thus, the induced job years created from building retrofits are estimated at 4.9 per $1 million of expenditures. Most of the jobs created in building retrofits are in the construction and manufacturing industries with a wide range of pay level and technical specialization including electricians, HVAC technicians, insulation installers, energy auditors, building inspectors, and construction managers.

Table 18: Employment Creation Impacts for Various Energy Sources from $1 Million of Expenditures (Source: Pollin et al., 2009)

Energy Source	Direct Job Creation per $1 million expenditures (# job-years)	Indirect Job Creation per $1 million expenditures (# job-years)	Direct and Indirect Job Creation per $1 million expenditures (# job-years)
Fossil Fuel			
Oil and Natural Gas	0.8	2.9	3.7
Coal	1.9	3.0	4.9
Energy Efficiency			
Building Retrofits	7.0	4.9	11.9
Mass Transit	11.0	4.9	15.9
Smart Grid	4.3	4.6	8.9
Renewables			
Wind	4.6	4.9	9.5
Solar	5.4	4.4	9.8
Biomass	7.4	5.0	12.4

In order to have a rough estimate of the new job opportunities associated with the proposed energy efficiency retrofit programs, the job creation model of Table 18 is applied to Kuwait. It is found that up to 127,937 new job years can be created when retrofitting the existing building stock in Kuwait as illustrated in Table 19. As noted earlier, most of the jobs created will be associated with retrofitting existing and privately owned residential buildings.

Table 19: Number of Job Years that Could be Created from Building Energy Efficiency Retrofit Programs in Kuwait

Building Type	Level-1	Level-2	Level-3
Private Residential	2321	23217	46434
Governmental Residential	12	83	167
Commercial	5438	27180	54371
Governmental	2701	13483	26965
Total	10460	63974	127937

Barriers for Energy Efficiency Policies Implementation

In Kuwait, several barriers exist to implement energy efficiency programs for buildings including more stringent mandatory building energy efficiency code for new buildings and a gradual mandatory national energy efficiency retrofit program as outlined in the previous sections. Among the most critical barriers for building energy efficiency in Kuwait are:

- **High energy subsidies**: costs of producing electricity (as well as water) are heavily subsidized in Kuwait like most of GCC countries. Due to the artificially low prices, end users in Kuwait and GCC countries lack awareness and desire to conserve energy and water resources. It is recommended that the Kuwaiti government gradually reduce these energy and water subsidies.
- **Separate rent and utility bills**: In Kuwait, it is common for landlords to combine rent with utility bills reducing any incentive for renters to conserve energy and water. Since there are over 2.8 million expatriates living in Kuwait needing to rent houses or apartment

units, it is important to separate rental fees from utility bills to promote conservation of energy and water consumption. Separate meters for all apartment units should be installed.

- **Lack of intelligent building operation**: The vast majority of buildings in Kuwait are air-conditioned 24-hour per day regardless of whether these buildings are occupied or not. The installation of intelligent control systems such programmable thermostats, daylighting controllers, occupancy sensors is needed to help improve the operation of buildings and thus reduce their energy consumption. The proposed national energy efficiency retrofit program can help introduce these intelligent control systems as well as energy efficient appliances and air-conditioning systems not only to the new buildings but to the existing building stock in Kuwait.
- **Delayed political decisions**: especially in the last decade, Kuwait has seen several infrastructure projects including power plants delayed or even eliminated because of slow application of regulations and reforms attributed to the difficult political climate and cumbersome administrative procedures. Some reforms are needed in order for the approval procedures associated with the implementation of key infrastructure projects and regulations to be accelerated and executed on a timely manner in Kuwait.

Conclusions and Recommendations

Kuwait has been the first Arab country to mandate energy efficiency code for new buildings in 1983. However, significant increase in energy consumption associated with buildings has been documented in Kuwait throughout the last two decade with a rate of increase in electricity consumption of more than 6%, one of the highest in the world. Several factors including the increase in the population, the high energy subsidies, and the lack of more stringent energy conservation code have contributed to the significant increase in electricity consumption in Kuwait.

As discussed in the report, the 2010 revision of the energy conservation code of practice provides a good stepping stone to improve energy efficiency of not only new buildings but also existing buildings in Kuwait. Indeed, the 2010 code regulations are more stringent and cover a wider range of energy efficiency technologies and can achieve about 23% energy savings compared to the 1983 code specifications. Some detailed simulation studies and energy efficiency retrofits have been reported in the literature and have showed that significant energy use savings can be achieved using common and proven energy efficiency techniques and technologies for implementation in new construction and for retrofitting existing buildings in Kuwait. The analyses have shown that the energy use savings can be achieved cost-effectively when the actual cost, rather than the subsidized cost, of generating electricity is taken into account. For instance, it has been found that energy savings up to 60% can be achieved economically for residential buildings in Kuwait.

While the application of the 2010 instead of 1983 energy conservation code of practice to new construction has some benefits (estimated to be 164 GWh/year in annual energy savings, 94 MW in electrical peak demand reduction, and 143 10^3 tons/year reduction in annual CO_2 emissions), the national energy efficiency retrofit program to consider the entire existing building stock has significantly higher economical and environmental benefits (up to estimated to be 8934 GWh/year in annual energy savings, 5105 MW in electrical peak demand reduction, and 7773 10^3 tons/year reduction in annual CO_2 emissions).

The main recommendations based on the series of the analyses presented in this report in order to further improving the energy efficiency performance of buildings in Kuwait are briefly summarized below:

1- Ensure that the energy conservation code of practice is updated at least once every 5 years to include more stringent regulations and proven energy efficiency technologies. This approach is common in most countries with well established building energy efficiency codes and standards. For instance, ASHRAE energy efficiency code in the US is updated every 3 years.
2- Start to implement gradually a mandatory energy efficiency retrofit program first for the residential building sector then for the entire existing building stock in Kuwait. Three levels of energy retrofit are evaluated in this report. It is found that a basic retrofit level (i.e., level-1 energy efficiency retrofit program) consisting of improving energy efficiency level of lighting and air conditioning systems can pay for itself through elimination of the capital costs needed for new electrical power plants.
3- Gradually reduce energy and water subsidies to ensure that deeper energy retrofit of existing building stock can become cost-effective even for building owners. Without any reduction in subsidies, level-2 and level-3 energy efficiency retrofit programs are now cost-effective for the Kuwaiti government, but not for the end users, due to the avoided costs of the subsidies as a result of the implementation of the measures. When the level of subsidies decreases, the measures become less cost effective for the government but more cost effective for the end users.

In addition to the significant economical and environmental benefits for improving the energy efficiency of both new and existing buildings in Kuwait, the energy retrofit program can create significant number of jobs in Kuwait (up to 127000 job years can created if all the building stock is retrofitted).

The mandatory building energy efficiency retrofit program can be applied not only in Kuwait but in any GCC country that provides high energy subsidies. Similar economical and environmental benefits found for Kuwait can be obtained for other GCC countries.

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Appendix A: Building Energy Conservation Code of Practice of 1983 and 2010

Table A-1: Requirements of 1983 Code of Practice for Building Energy Conservation

Requirements		**Value**	
Maximum Lighting power		15 W/m^2 (1.39 W/ft^2)	
Maximum DX Power		65 W/m^2 (6.04 W/ft^2)	
Maximum power rating for A/C system		2 kW/RT at 48^{o}C (COP is about 2 at 35^{o}C)	
Glazing Type	WWR	Window type	
	0 - 10	Any type	
	11 - 15	Any type of double glazing	
	More than 15	Type of double glazing is left to designer and building owner to obtain required W/m^2	
Maximum overall U in W/m^2.K (Btu/h.ft^2.F)		Wall	Roof
	Heavy Const. Med. – light external color	0.568 (0.1)	0.397 (0.07)
	Any other Const.	Should be reduced to have the equivalent thermal gain	Should be reduced to have the equivalent thermal gain

Table A-2: Maximum U-values for Walls and Roofs in Kuwait using 2010 Code of Practice

Construction Type*	**U_{max} for Exterior Walls W/m^2.^{o}C (Btu/hr.ft^2.^{o}F)**	**U_{max} for Roofs W/m^2.^{o}C (Btu/hr.ft^2.^{o}F)**
Heavy Construction with medium-light external Color	0.568 (0.100)	0.397 (0.070)
Heavy Construction with dark external Color	0.426 (0.075)	0.256 (0.045)
Medium Construction with medium-light external Color	0.483 (0.085)	0.341 (0.060)
Medium Construction with dark external Color	0.426 (0.075)	0.199 (0.035)
Medium Construction with medium-light external Color	0.426 (0.075)	0.284 (0.050)
Medium Construction with dark external Color	0.369 (0.065)	0.170 (0.030)

* constructions are classified by their mass per unit area as follow: heavy (above 485 kg/m^2 for walls and above 245 kg/m^2 for roofs), medium (between 245 and 480 kg/m^2 for walls and between 125 and 240 kg/m^2), and light (below 240 kg/m^2 for walls and below 120 kg/m^2 for roofs)

Table A-3: Maximum Window-to-Wall Ratio for Glazing Types in Kuwaiti Buildings for 2010 Code of Practice

Glazing Type* (6-mm)	SHGC	T_v	U-value ($W/m^2.^oC$)	Window-to-Wall Ratio (WWR)			
				East	West	South	North
Single-Clear	0.72	0.80	6.21	< 5	< 3	< 4	< 5
Single-Reflective	0.31-0.37	0.16-0.27	6.41-6.44	6-10	3-10	4-10	6-10
Double-Tinted	0.36-0.40	0.30-0.57	3.42-3.44	11-15	10	10	11-15
Double-Reflective	0.245	0.228	3.38	16-50	10-45	10-45	16-50
Double-Selective	0.230	0.530	1.71	51-100	45-75	45-75	51-100

*Properties for glazing include: Solar Heat Gain Coefficient (SHGC), Visible Transmittance (T_v), and Heat Transmission U-value

Table A-4: Lighting and Air-Conditioning Power Density Requirements for Kuwaiti Buildings for 2010 Code of Practice

Building Type	Lighting (W/m^2)	Air Conditioning Systems (W/m^2)				
		Direct Expansion	Air-Cooled Chillers	Water-Cooled Chillers		
				< 250 RT	250 <RT<500	>500 T
Residential Buildings (Villas or Apartments)	10	60	71	53	46	44
Office Buildings	20	70	82	62	54	51
Clinics and Hospitals	20	85	100	75	65	63
Schools	20	100	118	88	76	74
Mosques (Prayer Rooms)	20	115	135	101	88	85
Fast Food Restaurants						
- Standalone	20	145	171	128	111	107
- In Malls	20	120	141	106	92	88
Shopping Malls	40	70	82	62	54	51
Standalone Shops	40	80	94	71	61	59
Theaters, Dinning Halls, and Community Halls	20	115	135	101	88	85
Show Rooms	40	115	135	101	88	85

Table A-5: Occupancy Density and Outdoor Air Ventilation Requirements for Kuwaiti Buildings (Source: ASHRAE Standard 62-2001)

Building Type	Occupancy per 100 m^2 of floor area	Outdoor Air Ventilation Requirements			
		Occupancy-Based		Floor Area-Based	
		CFM/person	L/s.person	CFM/ft^2	L/s.m^2
Residential Buildings					
- Living areas		15	7.5		
- Kitchen		25	12		
- Bathrooms and toilets		20	10		
Office Buildings					
- Office spaces	7	20	10		
- Reception areas	60	15	8		
- Conference rooms	50	20	10		
Schools					
- Classrooms	50	15	8		
- Laboratory spaces	30	20	10		
- Libraries	20	15	8		
- Auditorium spaces	150	15	8		
Hotels					
- Bedrooms		30/room	15/room		
- Living rooms		30/room	15/room		
- Bathrooms and toilets		35/room	18/room		
- Lobby areas	30	15	8		
- Conference rooms	50	20	10		
Assembly Halls	120	15	8		
Dormitories	20	15	8		
Eating and Drinking Spaces					
- Dining rooms	70	20	10		
- Cafeteria and fast-food areas	100	20	10		
- Kitchen and cooking areas	20	15	8		
Hospitals					
- Patient Rooms	10	25	13		
- Operating Rooms	20	30	15		
- ICU and recovery rooms	20	15	8		
Garages and Warehouses					
- Enclosed parking spaces				1.5	7.5
- Auto repair rooms				1.5	7.5
- Warehouses	5			0.05	0.25
- Factory areas				0.10	0.50
Sports and Amusement Buildings					
- Spectator areas	150	15	8		
- Game rooms	70	25	13		
- Swimming pools/deck areas				0.5	2.5
- Gymnasium areas	30	20	10		
- Ballrooms	100	25	13		
- Bowling alleys	75	25	13		

Table A-6: Minimal Values for Power Factor and Efficiency Allowed for Electrical Motors and Lighting Fixtures for 2010 Code of Practice

Type of Electrical Motor and Lighting Fixture	Minimum Value for Full-Load Power Factor	Minimum Value for Full-Load Motor Efficiency (%)
Single-Phase Motors (240 V; 1450 rpm; 50 Hz)	0.80	35-80
Three-Phase Motors (415 V; 1500 rpm; 50 Hz)		
- 15 HP < Capacity < 50 HP	0.83	86-89
- 50 HP < Capacity < 100 HP	0.85	89-90
- 100 HP < Capacity < 200 HP	0.87	90-91
- 200 HP < Capacity < 400 HP	0.88	93-94
- Capacity > 400 HP	0.89	>94
Fluorescent and discharge Lamps	0.90	-

Table A-7: Maximum Values for Power Rating Allowed for Air-Conditioning (A/C) Systems based on 2010 Code of Practice

A/C System	Capacity (RT)	Power Rating (kW/RT)					
		Chiller	Cooling Tower Fan	Condenser Water Pump	Chiller Water Pump	Air Handling Fan	Total A/C System
Ducted split and packaged units	all						1.70
Air-cooled	all	1.60			0.05	0.35	2.00
Water-cooled	< 250	0.95	0.04	0.06	0.07	0.38	1.50
	250-500	0.75					1.30
	>500	0.70					1.25

Appendix B: Cost-Effectiveness of Optimal Energy Efficient Designs for Residences in Kuwait

Table B-1 summarizes the basic characteristics of a prototypical single-family house considered in the optimization analysis of Krarti and Ihm (2014). Figure B-1 provides a 3-D rendering of the prototypical home (often, referred to as a villa). The residential building has 3 bedrooms and 2 living rooms and is air conditioned with a split system. Throughout the year, a thermostat is utilized to maintain indoor thermal comfort with a cooling set-point of 24℃ during summertime, and a heating set-point of 22℃ during wintertime. The analysis is carried out using the government perspective. For details, refer to Krarti and Ihm (2014).

Table B-1: Characteristics of a prototypical single-family residential building

Number of floors	2 stories
Floor area	221 m² (2,379 ft²)
Floor-to-floor height	3 m (9.8 ft)
Exterior wall area	381 m² (4,101 ft²)
Window area	95.2 m² (1,025 ft²)
Window-to-wall ratio	25% of all directions
Number of bedrooms	3
Number of bathrooms	2
Cooling System	Split system residential air conditioner
Heating System	Baseboard

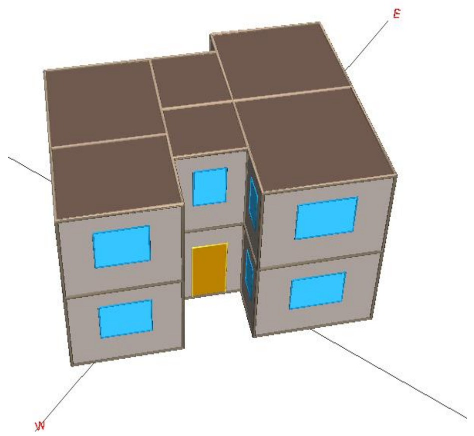

Figure B-1: Isometric view of an energy model for a prototypical residential building

Impact of Utility Rates

The cost of electricity to the consumers is highly subsidized in Kuwait. To assess the impact electricity costs, the effects of the increasing utility rates from 0% to 200% are analyzed in this section to determine optimal energy efficiency package for a residence in Kuwait. Figure B-2 provides LCC ratio to baseline LCC as a function of source energy savings for various increase levels of utility electricity rates when the residential building is located in Kuwait city. The optimal paths of LCC ratio as a function of source energy savings is affected significantly by the cost of energy. In particular, the optimal source energy savings is increased from 59% to 67% as the utility rates are increased from 0% to 200% as shown in Figure B-2. Meanwhile, the optimal LCC ratios are decreased from 0.75 to 0.53.

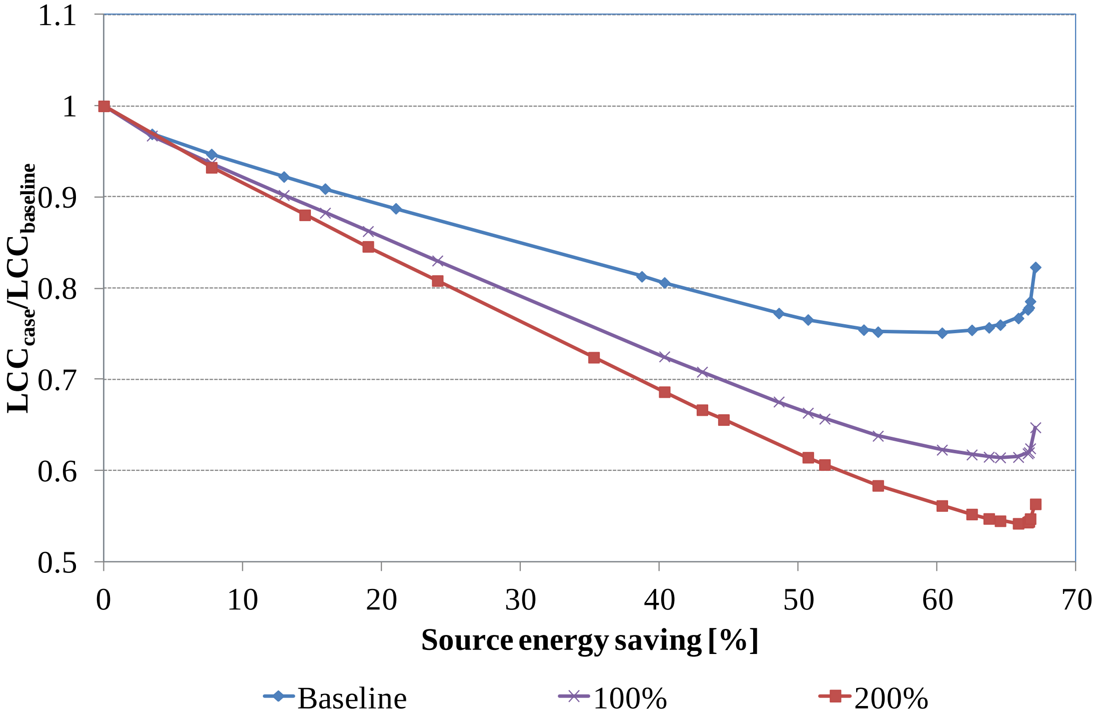

Figure B-2: Life cycle cost ratio as a function of source energy savings for Kuwait as a function of increase level of utility rates for five selected cities in the GCC

Impact of EEM costs

Figure B-3 illustrates the optimal paths to design an energy-efficient residential building when the costs of EEM options are varied from -60% (reduction) to 60% (increase) for the prototypical residential building located in Kuwait. With higher EEM costs, optimal LCC ratios are increased while optimal source energy savings are decreased. Specifically, when the EEM implementation costs increase from 0 to 60%, the optimal LCC ratio increases from 0.75 to 0.83 and the optimal source energy savings are slightly reduced from 59% to 57%. However, when the EEM implementation costs decrease from 0 to -60%, the optimal LCC ratio is reduced from 0.75 to 0.57 and the optimal source energy savings are noticeably increased from 59% to 67%. Indeed, lower costs for EEM options results in additional energy efficient features to be cost-effective in designing residential buildings and consequently to higher source energy use savings and lower LCC values as shown in Figure B-3 for Kuwait.

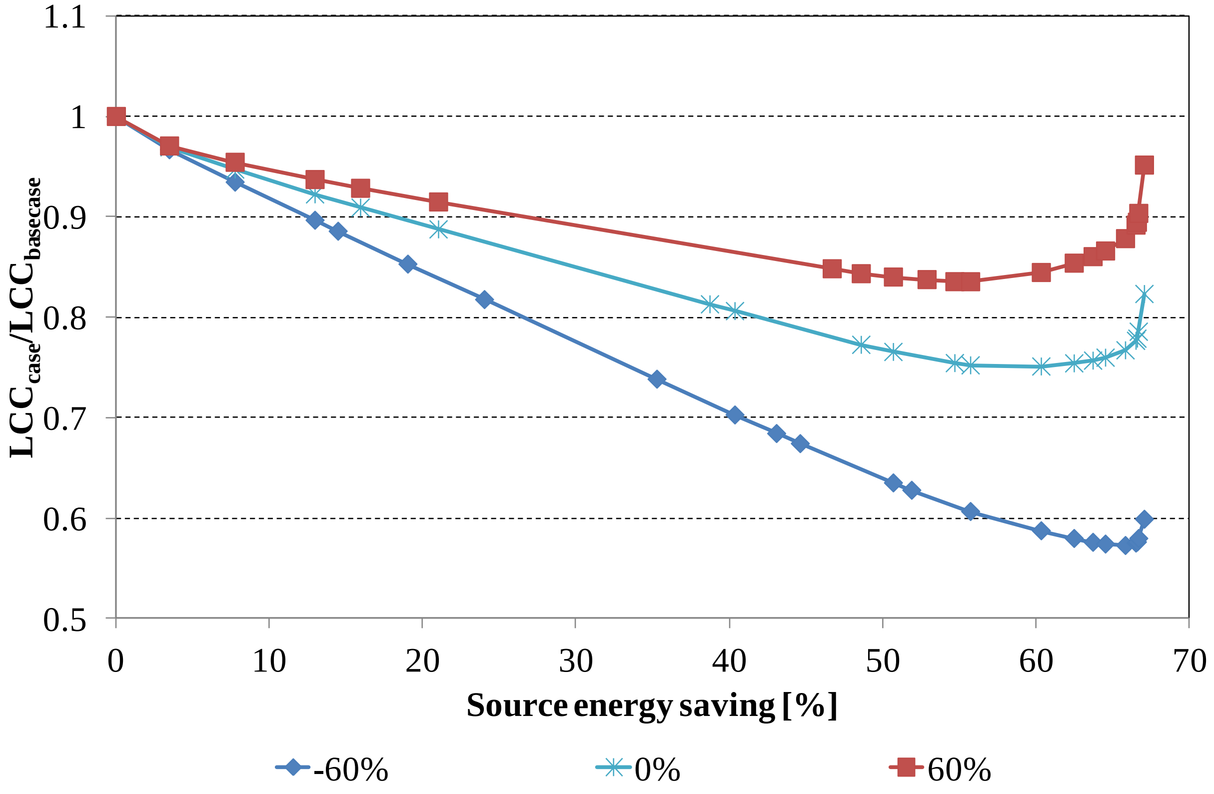

Figure B-3: Life cycle cost ratio as a function of source energy savings for a residential building in Kuwait and the cost of energy-efficient measure increase.