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DEVELOPMENT OF A LIGHTING REGULATION IN THE UAE

Technical Reports & Policy Options for the Implementation of the New Lighting Regulation and a Reduced Ecological Footprint

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Emirates Wildlife Society is a national (UAE) environmental non-profit organization established under the patronage of HH Sheikh Hamdan bin Zayed Al Nahyan: Ruler's Representative in the western region and Chairman of Environment Agency-Abu Dhabi (EAD). EWS works in association with WWF, one of the world's largest and most respected independent conservation organizations. EWS-WWF has been active in the UAE since 2001 and has initiated and implemented several conservation and education projects in the region. The mission of EWS-WWF is to work with people and institutions within the UAE and the region, to conserve biodiversity, tackle climate change and reduce the ecological footprint through education, awareness, policy, and science-based conservation initiatives.

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About the UAE Ecological Footprint Initiative

The Ecological Footprint Initiative (EFI) was launched in 2007 through a partnership between: the Ministry of Environment and Water, Environment Agency – Abu Dhabi, EWS-WWF and the Global Footprint Network, transforming the UAE from a country with one of the highest per capita Ecological Footprint per capita the world, to one with some of the most advanced Ecological Footprint science. From 2007-2011, the Ecological Footprint Initiative succeeded in verifying the UAE footprint, identifying the breakdown of the footprint by sector and developed a scientific scenario-modelling tool for decision makers that assesses the impact of different policies to reduce the country's footprint to 2030. In 2012, the partnership welcomed the Emirates Authority for Standardization and Metrology which worked on developing energy efficiency standard for domestic lighting. The Ecological Footprint Initiative continued to verify the UAE's Footprint, and finding solutions to manage the country's Footprint.

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This volume of technical reports, titled "Development of a Lighting Regulation in the UAE", is the culmination of the work done by RTI for the lighting regulation. This volume contains four reports: Baseline Assessment; Technical, Economic and Achievable Potential; Sustainability Impact Assessment; and Policy and Regulatory Frameworks. These reports detail the assumptions, methodologies, and key results of the study which were used to develop the standard itself along with its appendices.

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The successful partnership of the EFI highlights the importance of conducting locally relevant science-based research to support policy making. In particular, the close collaboration with ESMA resulted in these reports being used as supporting documents to develop the “UAE Regulation for Lighting Products”, which was approved by the UAE Cabinet and HH Sheikh Mohamed bin Rashid Al Maktoum, Prime Minister of the UAE and Ruler of Dubai, in December 2013.

The “Development of a Lighting Regulation for the UAE” report has been prepared by Research Triangle Institute International (RTI International) for EWS-WWF. We specifically thank Dr. Michael P Gallagher, Mr. Rick Marinshaw, Mr. Glenn Osmond, and Mr. Keith Weitzof RTI International for their efforts and effective collaboration with us while drafting the reports.

We also recognise that the Middle East Lighting Association (MELA),provided technical expertise, insight, constructive collaboration and critical data to develop these reports and the subsequent development of the “UAE Regulation for Lighting Products”.

We are grateful to allstakeholders that contributed with data and technical expertise to make these reports robust and locally relevant. These include but are not limited, to The Ministry of Environment and Water, Environment Agency – Abu Dhabi, The Emirates Authority for Standardisation and Metrology, Regulation and Supervision Bureau – Abu Dhabi, The Middle East Lighting Association, Department of Municipal Affairs - Abu Dhabi, The Executive Affairs Authority - Abu Dhabi, The Urban Planning Council - Abu Dhabi, Abu Dhabi Water and Electricity Authority, Dubai Carbon Centre of Excellence, Dubai Electricity and Water Authority, Dubai Statistics Centre, Federal Electricity and Water Authority, Fujairah Municipality Health Department, Masdar Institute, Ministry of Economy, Ministry of Public Works, National Bureau of Statistics, and Sharjah Electricity and Water Authority.

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EWS-WWF has been actively working in the UAE since 2001 to conserve biodiversity, tackle climate change and reduce the country's ecological footprint.

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Director General of EWS-WWF

Through our collaborative work on the Ecological Footprint Initiative (EFI)and the dedicated commitment from the partners of the EFI, namely the Ministry of Environment and Water, Emirates Authority for Standardisation and Metrology (ESMA), Environment Agency – Abu Dhabi (EAD) and the, Global Footprint Network (GFN), and our Steering Committee, the EFI wasable to technically support the development of the recently approved "UAE Regulation for Lighting Products".

As lighting offers the second highest energy saving potential in the UAE after cooling, the EFI undertook a close partnership with ESMA to support the authority in the development of a regulationfor indoor lighting products as a viable and impactful route towards lowering the country's carbon footprint. This work was supported by research conducted by the Research Triangle Institute International (RTI International) on the technical and economic potential, and the sustainability impacts of implementing a lighting regulation in the UAE.

It is well recognised that globally a switch to energy efficient lighting and energy efficiency are very effective strategies to mitigate climate change. This is confirmed for the UAE, where the results of our research show that the lighting regulation will bring significant environmental and economic benefits to the UAE, all estimated under a conservative scenario. The environmental gains alone will bring substantial carbon emission reductions of 940,000 tonnes of CO_2e, which is the same as removing 165,000 cars off the road annually. Meanwhile, implementing this standard will mean financial savings estimated at AED 668 million annually for the country.

The technical reports, now collected in 1 volume under the title "Development of a Lighting Regulation in the UAE", were used as consultation documents during the extensive stakeholder engagement led by ESMA with federal and local governmental entities, lighting industry, waste management entities, and civil society. These reports, along with feedback from stakeholders, informed the framework of the approved regulation. They can also provide decision makers with a basket of policy options to choose from and effectively implement the regulation within their jurisdiction.We hope that they continue offering valuable information and analysis that can be used by others in academia, research and policy making to further advance science-based policy making in the UAE.

I thank our esteemed EFI partners, our Steering Committee Members, our sponsors(EAD and RSB – Abu Dhabi) and relevant stakeholders, for contributing to the development of these reports. Their efforts led to the successful approval of the "UAE Regulation for Lighting Products" by the UAE Cabinet and HH Sheikh Mohamed bin Rashid Al Maktoum (Prime Minister of the UAE and Ruler of Dubai) in December 2013. This is one of many successes we anticipate for the Ecological Footprint Initiative, and for the UAE.

TECHNICAL MEMORANDUM 1

BASELINE ASSESSMENT

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LIST OF ABBREVIATIONS

AGEDI.......... Abu Dhabi Global Environmental Data Initiative
AP.......... Achievable Potential
B/C.......... benefit cost
CAIT.......... Climate Analysis Indicators Tool
CCP.......... Comprehensive Cooling Plan
CDDM-SSC-PDD.......... Clean Development Mechanism Project Design Document Form
CDM.......... Clean Development Mechanism
CFL.......... compact fluorescent lamp
CH_4.......... methane

CO_2 .... carbon dioxide
CO_2eq .... CO_2 equivalents
DCCE .... Dubai Carbon Center of Excellence
DEWA .... Dubai Electricity and Water Authority
DMA .... Abu Dhabi Department of Municipal Affairs
DSC .... Dubai Statistics Center
DSM .... demand-side management
EAA .... Abu Dhabi Executive Affairs Authority
EEL .... energy-efficient lighting
EF .... ecological footprint
EFI .... Ecological Footprint Initiative
EMCS .... Energy management control system
EP .... Economic Potential
EPA .... U.S. Environmental Protection Agency
ESMA .... Emirates Authority for Standardization and Metrology
EU .... European Union
EWS-WWF .... Emirates Wildlife Society in association with the World Wide Fund for Nature
FEWA .... Federal Electricity and Water Authority
GFN .... Global Footprint Network
GHG .... greenhouse gas
HID .... high intensity discharge
IECC .... *International Energy Conservation Code*
IRR .... internal rate of return
LCA .... life-cycle assessment
LED .... light-emitting diode
LPD .... lighting power density
MC .... Marginal Cost
MELA .... Middle East Lighting Association
MEPS .... Minimum Efficiency Performance Standard
MoEW .... Ministry of Environment and Water
N_2O .... nitrous oxide
NBS .... National Bureau of Statistics
NOx .... nitrogen oxide
PB .... payback
PBRS .... Pearl Building Rating System
PM .... particulate matter
RTI .... RTI International
SSL .... solid-state lighting
SOx .... sulfur oxides
TP .... Technical Potential
UAE .... United Arab Emirates
UPC .... Abu Dhabi Urban Planning Council
WEEE .... Waste Electrical and Electronic Equipment
WWF .... World Wide Fund for Nature

1. Introduction

This report presents the baseline assessment for the development of residential lighting standards for the United Arab Emirates (UAE). The baseline assessment is a snapshot of the current situation with respect to lighting in the residential sector, based on the best-available information. This assessment includes a profile of electrical lighting in the residential sector of the UAE and an estimate of annual electricity consumption that can be attributed to lighting in the sector. Establishing a baseline is one of the first steps in developing a lighting standard and is used as a point of comparison for the various options considered in developing lighting standards. For this assessment, the baseline year is assumed to be 2011.

The baseline assessment is one part of an overall study, *Development of Lighting Standards for the United Arab Emirates*, to establish the basis and recommendations for developing residential lighting standards for the UAE. Section 1.1 explains the background and purpose of this study and includes a description on the tasks to be conducted. The remainder of this section describes the organization of this report and the data requests used to provide information needed for this study.

1.1 Background and Purpose

The UAE has one of the highest per capita carbon footprints in the world and a growing gap between demand and supply of energy (WWF, 2012). In combination with being a rapidly developing country and growing population, the UAE is facing an urgent need to evaluate and establish standards for reducing energy consumption in all sectors, including the residential sector, in a manner that is protective of the environment and of the country's economic and social well-being.

In 2007, the UAE's Ecological Footprint Initiative (EFI) was established through a partnership with the Ministry of Environment and Water (MoEW), the Environment Agency – Abu Dhabi (EAD)[1], the Emirates Wildlife Society in association with the World Wide Fund for Nature (EWS-WWF), the Global Footprint Network (GFN), and more recently, the Emirates Authority for Standardization and Metrology (ESMA) to manage its Ecological Footprint (EF) through research, policy, and practice. The knowledge gained from the EFI has benefited the country by creating opportunities for UAE government leaders and residents to move towards sustainable development.

The EFI continues to tackle the country's EF and began a new phase of work in 2012. Included in this scope of work is research to support ESMA in the development of an energy efficient lighting standard and labeling system for the UAE's residential sector.

The objective of the standard is to reduce energy consumption and carbon emissions while minimizing negative impacts on the UAE economy, environment, and human health. To this end, it is very important to understand the economic, environmental, health, and social implications for residents and for businesses and governmental agencies.

The residential sector was selected as the focus of this study for several reasons. First, the findings of the EFI, that households account for approximately 57% of consumption for the UAE, establish the residential sector as a clear target for improving energy efficiency. In addition, not only does lighting account for a significant percentage of electricity consumption in the residential sector, residential lighting historically has been provided mostly through the use of incandescent lamps, which are the least efficient of the lighting technologies currently in the market. On the other hand, lighting in the commercial, institutional (governmental and public), and industrial sectors is predominantly provided by linear fluorescent lamps, which are among the most efficient of lighting technologies. Compared to the residential sector, these other sectors also tend to be more conscious of energy efficiency and the cost of inefficiency, particularly when there is a financial incentive, as is the case for the commercial and industrial sectors. Furthermore, implementing energy efficiency is easier

[1] EAD was represented by its subsidiary body, the Abu Dhabi Global Environmental Data Initiative (AGEDI).

in these other sectors, where selection of lighting technologies can be made through company or institutional policy decisions, rather than the personal preferences of villa or apartment residents. Finally, if the savings that can be achieved through residential lighting standards can be demonstrated to be material and economical, it stands to reason that lighting standards for other sectors would be likewise.

The decision was made to focus on the carbon component because it accounts for 80% of the country's EF. Depending on location, lighting can account for as much as 20% of the electricity consumed by the residential sector (IEA, 2006) and thus, an increased emphasis is being placed on establishing energy-efficient lighting (EEL) and associated policy measures. Lighting also has an impact on cooling load because it can generate heat nearly equal to the number of watts consumed. Cooling is the largest electricity consuming activity in the UAE.

The UAE has the necessary institutional capacity to also develop such a standard as evidenced by the labeling system for room air conditioners developed by ESMA for the UAE. With an increased emphasis being put on demand-side management (DSM) measures to address the growing gap between demand and supply of energy in the UAE, EWS-WWF and ESMA are seeking to develop a robust energy-efficiency standard, labeling system and policy framework for lighting in the UAE's residential sector. This standard can then be expanded to cover public and private sectors as the country gains additional experience and stakeholder support.

1.2 Description of Overall Study

Figure 1 depicts the six tasks that comprise the *Development of Lighting Standards for the United Arab Emirates* study. The following paragraphs provide additional details on these tasks.

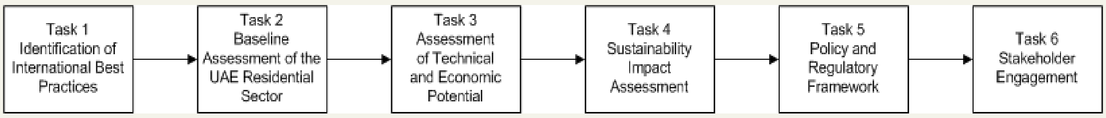

Figure 1. Flow Chart for Development of Lighting Standards for the United Arab Emirates

Task 1 consists of a review of international best practices. The best practices review will be used to benchmark, identify possible options, and provide a template for the lighting standard developed for the UAE.

Task 2 of the study is the baseline assessment of the residential sector in the UAE and includes a profile of the residential lighting sector and an estimate of electricity consumption for residential lighting in the baseline year. This document comprises the report for the baseline assessment.

Task 3 of the study consists of an assessment of the technical and economic potential for identified lighting standards. The goal of this assessment is to ensure that the policy or standard is within an acceptable range of cost and benefit in terms of energy savings potential, carbon savings potential, environmental and health trade-offs, recycling, and financial impacts.

Task 4 of the study encompasses a sustainability impact assessment. This assessment, which is a strategic tool to prevent or minimize adverse impacts to current and future generations, will cover several areas, including recycling of spent lighting products, mercury waste generation and fate, life-cycle material assessment, cost to consumers, human health effects, public perception, and energy and carbon savings.

Task 5 of the study uses the data gathered from the first four tasks (i.e., international best practices, current residential lighting usage, cost-benefit-analysis, and environmental impact analysis) to advise stakeholders of policy goals and framework recommendations that will support the reduction of the UAE's carbon footprint. The outcome of this task includes identification of the activities, capabilities, and regulatory frameworks needed for the successful implementation of lighting standards for the UAE. These will range from educational (which most likely will include workshops and stakeholder engagement) to enforcement (establishing compliance monitoring, verification, and enforcement programs).

Task 6 of the study, stakeholder engagement, is actually a key component of each of the prior tasks because the success of the study can only be assured if key decision makers across the government and the private and residential sectors are involved throughout the standard development process.

1.3 Organization of Report

Section 1 introduces and sets the stage for the analysis that is presented in the remainder of this report. Section 2 provides an overview of the approach used to develop the baseline. Sections 3 through 6 describe the data and assumptions used to carry out the approach described in Section 2. Section 7 presents the results of the baseline assessment, and references are listed in Section 8.

1.4 Data Requests

Prior to performing the baseline assessment, data requests were transmitted to several UAE government agencies and other stakeholders. Letters were transmitted by the Ministry of Environment and Water and EWS-WWF to key stakeholders; individual meetings were then held between EWS-WWF, ESMA and several stakeholders to explain the objectives of the study, outline specific data needs and how those data would be used, and answer questions. In addition to contacting stakeholders directly, the websites for several government organizations were accessed for additional information. Data collected for previous and ongoing studies sponsored by the government of Abu Dhabi also were used to supplement the data collected for this study. Finally, the results of a voluntary residential lighting survey conducted by EWS-WWF were incorporated into the baseline assessment.

The specific data sources and references used in the analysis are each described as they appear in this report. Full citations for all references considered for the analysis are provided in Section 8. **Table 1** lists the organizations that provided data for this effort.

Table 1. Summary of Data Provided by Government Agencies and Stakeholders

Organization	Data and Documents Provided
Abu Dhabi Department of Municipal Affairs (DMA)	▪ Accessible and Usable Buildings and Facilities Code ▪ Abu Dhabi International Energy Conservation Code ▪ Abu Dhabi International Property Maintenance Code
Abu Dhabi Executive Affairs Authority (EAA)	▪ Demand Side Management for Electricity and Water Use in Abu Dhabi ▪ Demand Side Management (DSM) Comprehensive Cooling Plan
Abu Dhabi Urban Planning Council (UPC)	▪ GIS Building and Plot Data ▪ North Island Master Plan, Building Conditions and Assessments ▪ Estidama Pearl Building Rating System (PBRS) – RE-R1 Energy Prescriptive Pathway ▪ Switch on to Green Lighting (flyer)
Dubai Carbon Center of Excellence (DCCE)	▪ Minutes of the 17 May 2011 Dubai Stakeholders meeting with respect to the 'Dubai CFL Project' held in the Emirate of Dubai ▪ DCCE Projects – Executive Summary ▪ Clean Development Mechanism Project Design Document Form (CDDM-SSC-PDD)
Dubai Electricity and Water Authority (DEWA)	▪ Summary of 2011 Electricity Consumption by Sector, Fuel Utilization, Electricity Generation Capacity, and Water Production Capacity ▪ Total and Average Electricity Consumption by Villas and Flats ▪ Calculation of the Grid Emission Factor for Electricity System of DEWA
Dubai Municipality	▪ Summary of Newly Permitted Buildings by total floor space from 2006 to 2011 ▪ Department of Buildings & Housing, Building Code Regulations & Construction Specifications ▪ Green Building Regulations and Specifications
Dubai Statistics Center (DSC)	▪ The Estimated Number of Housing Units by Type – Emirate of Dubai (2008 – 2010)
Emirates Authority for Standardization and Metrology (ESMA)	▪ IEC Standards for Lamp Safety and Performance ▪ Development of Regulation for Lighting Products
Federal Electricity and Water Authority (FEWA)	▪ Calculation of the Grid Emission Factor for Electricity System of FEWA
Fujairah Municipality Health Department	▪ Flyer on Energy and Environmental Conservation
Masdar Institute	▪ Technical Note: CO_2 Allocation for Power and Water Production in Abu Dhabi
Middle East Lighting Association (MELA)	▪ Sustainable Lighting Policy in the ME Region ▪ Lighting product sales and market share data for 2010 and 2011 ▪ Information on EELs planned for introduction to the UAE market and the potential impacts of a lighting standard on the lighting supply chain in the UAE
Ministry of Economy, Central Statistics Department	▪ ch2-Population and Vital Statistics2008.xls ▪ ch7-Building and Construction2008.xls
Ministry of Public Works	▪ Summary of Residential Housing Construction Projects by Emirate and Region from 2006 to 2011 ▪ Summary of Residential Housing Projects in Selected Emirates from 2006 to 2010 ▪ Floor Plan for National Housing Units (Villa Duplex) and Specifications for Electrical Equipment and Luminaires
National Bureau of Statistics (NBS)	▪ Methodology of Estimating the Population in UAE ▪ Housing Unit Definitions ▪ Household Income & Expenditure Survey 2007 – 2009 ▪ Preliminary Results of Population, Housing and Establishments Census, 2005

2. Overview of Approach

This section provides an overview of the approach used to estimate baseline electricity consumption for lighting by the residential sector in the UAE. The primary factors that affect lighting electricity consumption are discussed briefly. It should be noted that these factors apply to estimating electricity usage by lighting in existing (or future) residential units and should be distinguished from design criteria, which must account for numerous other factors, such as distance from the luminaire to the illuminated surface, reflectivity of the illuminated surfaces, and others.

After a discussion of the factors affecting electricity consumption, general approaches used to estimate lighting electricity consumption are briefly described. Finally, the approach used in this analysis is presented.

2.1 Factors that Affect Electricity Consumption for Lighting

Several factors affect the amount of electricity consumed by lighting over a designated period of time. The primary factors that contribute to electricity consumption include lamp technology, lamp rating, lamp efficacy, and the amount of time the lamp is in operation. For discharge-type lamps, including fluorescent and high intensity discharge (HID) lamps, the type of ballast is also a significant factor in the consumption of electricity. The following paragraphs discuss these factors in more detail.

Lamp technologies commonly used for interior lighting in the residential sector include incandescent, compact fluorescent lamp (CFL), linear fluorescent, halogen, and light-emitting diode (LED), also referred to as solid-state lighting (SSL). These same technologies may also be used for exterior residential lighting. However, HID lamp technologies, such as mercury vapor, metal halide, and high-pressures sodium, are often used for exterior lighting.

Lamp rating, or **wattage**, is a measure of how much electrical power a lamp uses under normal operating conditions. Rating typically is measured in watts (W) and can range from as low as a few watts, for certain decorative lamps, to several hundred watts.

Lamp efficacy refers to the efficiency of a lamp in converting electrical power to light. Efficacy is typically represented in units of lumens per watt (lm/W). Efficacy can range from about 10 lm/W for some incandescent lamps to more than 80 lm/W for some linear fluorescent lamps.

For lamp technologies that require **ballasts** (fluorescent and HID), it is important to consider the system efficacy for the entire luminaire; system efficacy accounts for the energy efficiency of both the lamps and the ballast. A ballast is a device that regulates that electrical current as needed to operate the lamp. The two general categories of ballast are electronic and magnetic; electronic ballasts are more efficient that are magnetic ballasts.

Operating hours vary by time of day, depending on the type of room or application. For example, lamps and luminaires located in bedrooms may be used extensively in the early morning and late night, but minimally during the day.

2.2 General Approaches to Estimating Lighting Electricity Usage

Various methodologies can be used to estimate how much electricity is consumed by lighting. A key determinant in deciding which methodology is more appropriate is the availability of data on lamp technologies in use. If detailed data are available on the actual types, numbers, and ratings of lamp technologies in use, and data are available or can be estimated for annual operating hours, annual electricity consumption for lighting can be readily estimated. This methodology is referred to here as the *lamp-based* approach. If detailed data are not available on lamp technologies, the electricity consumed by lighting can be estimated using recommended lighting levels, which is referred to here as the *illuminance-based* approach.

2.2.1 Lamp-Based Approach

The lamp-based approach generally provides more accurate estimates because it incorporates a measure of what is actually used in terms of lamp technologies. It is the basic approach used in developing the domestic lighting standards for the European Union (VITO, 2009), and in a recent study characterizing the lighting market in the United States (U.S. DOE, 2012a). For the EU study, data were compiled on the residential sector and existing stock of residential lamps used in several countries. Data also were compiled on annual operating hours. The data were used to calculate weighted averages of lamp wattage for each type of lamp technology, average number of lamps per household, number of households, and average annual operating hours by lamp technology type. For example, incandescent lamps were estimated to have a weighted average rating of 54 W and were operated an average of 400 hours per year (hr/yr). Data on rated lamp efficacies were compiled from lamp suppliers' data and catalogues, from which typical values were selected for the analysis, depending on the lamp technology and design (e.g., clear vs. frosted bulbs). For CFLs, a correction factor of 5% also was applied to account for additional losses related to the ballast.

For the U.S. study, similar data were collected. However, data were compiled on lamp technology and use by type of residential unit (e.g., single-family detached, single-family attached, multifamily) and type of room (e.g., bedroom, kitchen, hallway). Thus, rather than provide average annual usage by lamp technology, as was used in the EU study, the U.S. study provides data on average daily usage by room type. Lamp efficacy data were compiled from manufacturers' catalogues, and weighted averages were determined by lamp technology and design, taking into account ballast effects for CFLs, linear fluorescent, and other discharge-type lamps.

2.2.2 Illuminance-Based Approach

Illuminance is defined as the amount of light incident of a surface per unit area and typically is expressed in units of foot-candles (lumens per square foot [lm/ft^2]) or lux (lumens per square meter [lm/m^2]), which is the metric system unit. As noted above, the illuminance-based approach is generally less accurate because it relies more on recommended lighting design criteria rather than the lamp and luminaire technologies actually in use. In other words, instead of estimating electricity consumption based on specified numbers and types of lamps, as is the case for the lamp-based method, this method uses criteria to determine how much light is needed for a specified application or use, then makes assumptions on the types of lamp technologies used to provide the recommended illuminance. Although this approach avoids the need for data on actual lamps in use, data are needed on floor space in order to calculate the lighting required or recommended (i.e., number of lumens) for a specified application. In addition, the illuminance-based approach requires data or assumptions on the efficiency (efficacy) of the existing lighting stock in order to convert lumens required to watts consumed.

2.3 Approach Used for Baseline Assessment

2.3.1 Selection of Approach

The decision of which approach to use comes down to the type of data available. In addition to contacting various stakeholders for available information on lighting technologies, four specific actions have been undertaken or are being planned to collect data on the lamp technologies currently in use in the residential sector of the UAE:

1. Data request to lighting suppliers, through the Middle East Lighting Association (MELA), for data on lamps sales for the past 5 years;
2. Voluntary lighting survey, which requested respondents to inventory the numbers and types of lamps found in their residence;
3. Abu Dhabi building survey, which will cover approximately 1,500 buildings in Abu Dhabi and will collect data on building characteristics, including lighting technologies; and

4. Limited market survey, which collected data on the types of lamps found on the shelves of six stores in Abu Dhabi.

At the time of this writing, data have been collected from MELA, the voluntary lighting survey, and the limited market survey; additional information on the results of these data collection activities is provided in Section 6. The Abu Dhabi building survey is not expected to be completed until after September 2012.

Although the lamp-based approach is preferred, for the reasons explained previously, the level of detail in the data received to date is inadequate for using strictly a lamp-based approach to estimate baseline consumption. Instead, a combination of the lamp-based and illuminance-based approaches was used. Illuminance levels were used to determine basic lighting requirements by room type for each typology. Then, the data received through MELA and the voluntary survey were used to estimate the types and number of lamp types that could provide those lighting requirements.

As more data become available, the assessment will be refined to utilize any additional data that are materially different and would result in significant changes to the baseline. The rest of this section explains the specific steps taken to complete the baseline assessment.

2.3.2 Steps Used for Baseline Assessment

The seven steps used to determine the baseline assessment for lighting by the residential sector in the UAE are listed below and described in the following paragraphs. **Figure 2** shows a flow chart of the process:

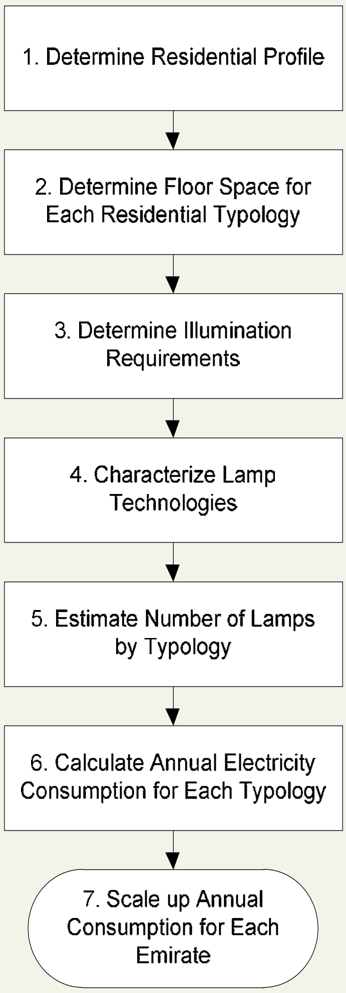

Figure 2. Flow Chart of Baseline Assessment Steps

1. Determine Residential Profile

The basic building block for assessing baseline electricity consumption for residential lighting is the residential housing unit. Thus, the first step was to create a residential profile by characterizing the residential sector in terms of the types of residential housing units and the numbers of each type. Recognizing that lighting usage is not likely the same across the population of residential units, several residential typologies were identified to characterize residential lighting. For example, annual lighting usage for a studio apartment is likely to differ significantly from annual lighting usage for a 3-bedroom apartment or a villa. Sections 3 and 4 describe the data used to develop the residential profile.

2. Determine Floor Space for Each Residential Typology

In order to determine lighting requirements based on illuminance, each residential typology must be defined in terms of the amount of floor space and how that floor space is used. That is, the criteria specify the minimum lighting required to adequately perform a specific task. In the residential sector, these criteria translate into differences in illuminance by type of room. For example, illuminance criteria for kitchens are generally greater than most other types of rooms because food preparation requires relatively high levels of lighting. Section 4 discusses residential typologies and floor space.

3. Determine Illumination Requirements

To determine specific illumination requirements, data on recommended illuminance were compiled and applied to a single residential unit within each residential typology at the room level. The product of illuminance and floor space provides the lighting requirements for a room in terms of lumens. Illumination requirements are addressed in Section 5.

4. Characterize Lamp Technologies

This step entails identifying the specific types of lamp technologies used in the residential sector. Section 6 of this report describes the available data on the types of lamps currently in use and how those data were used to characterize lamp technologies for estimating baseline consumption.

5. Estimate Number of Lamps by Typology

Using the illumination requirements determined through Step 3 and the lamp technology characterization in Step 4, the number of lamps was determined by room type, lamp technology, and residential typology.

6. Calculate Annual Electricity Consumption

Next, annual electricity consumption was estimated for each residential typology by applying values for lighting usage or operation, typically in units of hours per day (hr/day), to the number of lamps determined in Step 5.

7. Scale up Annual Consumption for Each Emirate

The final step was to determine annual lighting consumption across the UAE by scaling up the electricity consumption for each residential typology by the estimated number of housing units in each Emirate. Section 7 presents the results of electricity consumption estimates.

Basic Formula for Calculating Annual Electricity Consumption

To determine the annual electricity consumption, the following basic formula was used:

$$\sum_{i=1}^{i=j} N_i \times R_i \times U_i \times 365 \div 1{,}000$$

where:

j = Number of different lamp technologies
N_i = Number of lamps of type i
R_i = Rating of lamp i, watts
U_i = lighting usage rate, hours per day (hr/day)
365 = days per year (day/yr)
1,000 = watt-hours per kilowatt-hr (kW-hr)

3. Population and Growth Rates

As discussed in Section 2, the baseline assessment uses residential housing units as the basic building blocks. Therefore, a methodology is needed to project the number of housing units from the year represented by the housing unit data to later years. For example, to determine the number of housing units in 2011 based on the most recent census data (2005), it is necessary to project the number of each type of housing unit from 2005 to 2011. In the absence of data on the current and number of housing units and future projections of housing units, it was assumed that housing units would track population growth. The remainder of this section discusses historical data on the population of the UAE and the growth rates derived from the data.

3.1 Summary of Historical Data

Two references were obtained that provide historical data on the population of the UAE by year. The first reference includes a summary of the population of each Emirate for each year from 1996 to 2009 (ME/CSD, 2008a), as shown in **Table 2**. Although the file was obtained from the National Bureau of Statistics (NBS) website, the file identifies the source of the data as the Ministry of Economy – Central Statistics Department.

Table 2 also shows the estimated annual growth rate for each Emirate and for the overall population growth rate for the UAE based on the historical data. Growth rates range by Emirate from 3.3% to 7.3%, and the overall growth rate for the UAE is estimated to be 5.8%.

Table 2. Summary of Population by Emirate – 1996 to 2009 (ME/CSD, 2008a)

Year	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
1996	960,000	707,000	417,000	125,000	37,000	146,000	78,000	2,470,000
1997	996,000	747,000	444,000	132,000	37,000	152,000	82,000	2,590,000
1998	1,034,000	788,000	475,000	138,000	39,000	157,000	86,000	2,717,000
1999	1,073,000	832,000	508,000	147,000	40,000	164,000	91,000	2,855,000
2000	1,115,000	878,000	543,000	154,000	41,000	170,000	94,000	2,995,000
2001	1,156,000	949,000	581,000	163,000	42,000	176,000	100,000	3,167,000
2002	1,204,000	1,020,000	623,000	171,000	43,000	184,000	104,000	3,349,000
2003	1,257,000	1,098,000	667,000	182,000	46,000	191,000	110,000	3,551,000
2004	1,312,000	1,182,000	715,000	190,000	48,000	198,000	116,000	3,761,000
2005	1,399,484	1,321,453	793,573	206,997	49,159	210,063	125,698	4,106,427
2006	1,430,000	1,372,000	821,000	212,000	50,000	214,000	130,000	4,229,000
2007	1,493,000	1,478,000	882,000	224,000	52,000	222,000	137,000	4,488,000
2008	1,559,000	1,596,000	946,000	237,000	53,000	231,000	143,000	4,765,000
2009	1,628,000	1,722,000	1,017,000	250,000	56,000	241,000	152,000	5,066,000
Growth Rate, %	4.2%	7.3%	7.2%	5.5%	3.3%	3.9%	5.3%	5.8%

The second reference for population data is entitled *Methodology of Estimating the Population in UAE* and was also obtained from the NBS website. This document provides estimates of the total population of the UAE from 2006 to 2010 based on data on natural increase and migration. The document also provides the number of Nationals by Emirate for the same period of time. However, the non-National population is only presented for the entire UAE and not for individual Emirates. To estimate total population for each Emirate, it was assumed that the distribution of non-Nationals among the Emirates was comparable to the distribution of Nationals. For example, the data for 2010 show that 42.7% of Nationals lived in Abu Dhabi, so it was assumed 42.7% of the non-National population resided in Abu Dhabi. **Table 3** summarizes the resulting distribution.

Table 3. Summary of Population by Emirate – 2006 to 2010 (NBS, 2010)

Year	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
2006	2,129,623	849,739	831,984	234,948	95,623	528,731	341,736	5,012,384
2007	2,646,932	1,070,771	1,022,535	287,342	117,445	650,262	423,719	6,219,006
2008	3,441,024	1,405,426	1,319,243	367,537	151,059	838,478	550,860	8,073,626
2009	3,497,834	1,444,719	1,331,020	367,681	151,950	846,275	560,517	8,199,996
2010	3,526,590	1,464,776	1,336,944	367,752	152,398	850,199	565,411	8,264,070
Estimated Annual Growth Rates								
2006 to 2008	27.1%	28.6%	25.9%	25.1%	25.7%	25.9%	27.0%	26.9%
2008 to 2010	1.24%	2.09%	0.67%	0.03%	0.44%	0.70%	1.31%	1.17%
2006 to 2010	13.7%	14.9%	12.9%	12.1%	12.6%	12.9%	13.7%	13.6%

Using the 2005 populations reported in the Census (see Table 2) as the starting pointing, the data presented in Table 3 show large increases in populations from 2005 to 2008. The growth rates defined by these increases vary by Emirate from 25.1% to 28.6% and average 26.9% overall for the entire UAE. The data from 2008 to 2010 exhibit much smaller growth rates, which range by Emirate from 0.03% to 2.09% and average 1.17% overall for the UAE, reflecting the recent downturn in the global economy starting in 2008. If the data for the entire period from 2006 to 2010 are considered, the average annual growth rates range by Emirate from 12.1% to 14.9%; for the entire UAE, the overall growth rate for this period is 13.6%.

3.2 Estimated Growth Rates by Emirate

The two references described above show marked differences in the total population and population growth rates. For example, based on the overall growth rate derived from the data shown in Table 1(ME/CSD, 2008a), the population of the UAE would increase from 5.3 million in 2010 to 9.5 million in 2020. Using data for 2008 to 2010 summarized in Table 2 (NBS, 2010), the population of the UAE would increase from 8.3 million in 2010 to about 9.3 million in 2020; using the data for 2006 to 2008, the population would increase from 8.3 million in 2010 to more than 140 million in 2020; and using the data for 2006 to 2010, the population would increase from 8.3 million in 2010 to about 32.6 million in 2020.

In view of the inconsistency in growth rates since 2005, the historical population data from 1996 to 2005, as shown in Table 2, were used to estimate average growth rates from 2010 to 2020. These growth rates were applied to the estimated population for 2010 shown in Table 3, which reflects the most recent data available on the population of the UAE. **Table 4** shows the growth rates and estimate population by Emirate for 2010 to 2020.

Table 4. Projected Population by Emirate – 2010 to 2020

Year	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Growth Rate, %	4.1%	7.0%	7.2%	5.6%	3.4%	4.0%	5.2%	5.6%
2010	3,526,590	1,464,776	1,336,944	367,752	152,398	850,199	565,411	8,264,070
2011	3,672,279	1,567,552	1,433,480	388,329	157,511	884,280	594,997	8,698,429
2012	3,823,988	1,677,539	1,536,986	410,058	162,797	919,726	626,132	9,157,226
2013	3,981,964	1,795,242	1,647,966	433,002	168,259	956,594	658,897	9,641,924
2014	4,146,466	1,921,205	1,766,960	457,230	173,905	994,939	693,375	10,154,081
2015	4,317,763	2,056,006	1,894,546	482,814	179,741	1,034,822	729,658	10,695,349
2016	4,496,138	2,200,265	2,031,344	509,829	185,772	1,076,303	767,840	11,267,490
2017	4,681,881	2,354,646	2,178,020	538,356	192,005	1,119,447	808,019	11,872,374
2018	4,875,298	2,519,859	2,335,286	568,479	198,448	1,164,320	850,301	12,511,992
2019	5,076,705	2,696,664	2,503,909	600,288	205,107	1,210,992	894,796	13,188,461
2020	5,286,433	2,885,874	2,684,707	633,876	211,989	1,259,535	941,619	13,904,034

4. Residential Housing Unit Types

This section discusses the residential housing unit types and floor space calculations by typology (see Section 4.2) used for the baseline assessment. The available data are discussed first, followed by a discussion of the specific residential unit typologies used in the analysis.

4.1 Summary of Available Data

The currently available data on the numbers, types, and characteristics of residential housing units are from the NBS website, the Dubai Statistics Center website, and data collected previously from the Abu Dhabi Urban Planning Council for the ongoing Demand Side Management (DSM) work for Abu Dhabi Emirate. The following paragraphs describe the available data. See Table 1 for a complete list of data requested and collected as part of this study.

4.1.1 NBS Data

The NBS website includes a link to a file that contains historical data on housing units in the UAE from 1980 to 2005. The most recent data, for the year 2005, lists nine categories of housing units and indicates the number for each Emirate. **Table 5** summarizes the data.

Table 5. Number of Housing Units in 2005 (ME/CDS, 2008b)

Type of housing unit	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Flat	117,981	141,114	114,904	24,414	1,379	5,573	5,619	410,984
Villa	19,192	42,561	11,498	3,506	825	5,245	1,699	84,526
Part of Villa	4,290	914	846	319	13	310	69	6,761
One-story Building	19,965	0	5,068	1,778	770	4,298	2,759	34,638
Public House	26,310	0	9,528	1,779	1,543	6,637	4,497	50,294
Part of Public House	14,720	0	1,273	411	73	259	440	17,176
Separate Room(s)	17,799	2,841	10,868	2,322	560	2,239	1,728	38,357
Arabic House	0	15,987	10,760	4,411	3,306	13,694	2,111	50,269
Others	22,067	2,101	2,397	760	359	1,560	610	29,854
Total	242,324	205,518	167,142	39,700	8,828	39,815	19,532	722,859

It should be noted that a separate document (ME, 2006) with housing unit estimates also was obtained from the NBS website, but that document was not used because it predates the data shown in Table 4 and characterizes the data as preliminary results.

4.1.2 Dubai Statistics Center

The Dubai Statistics Center (DSC) reports data on housing units in the Dubai Emirate. However, the housing unit categories differ slightly from those reported by NBS. The most recent data on the DSC website cover the period 2008 to 2010 and are summarized in **Table 6**. The categories of housing units are similar to those reported in the NBS data and summarized in Table 4, but there are some differences in terminology and categories. For example, instead of *Part of Villa*, the DSC has a category of *Villa Supplement*, which is assumed to represent the same type of housing unit. Similarly, the DSC data include a category called *Collective residence*, which is assumed to be comparable to *Public House*.

Table 6. Estimated Number of Housing Units in Dubai Emirate (DSC, 2011)

Type of housing unit	2008	2009	2010
Flat	199,136	238,621	280,626
Villa	56,820	59,606	65,064
Villa supplement	1,096	860	896
Arabic House/Part of Arabic House	15,987	13,990	13,766
Room/Rooms	4,094	2,487	2,458
Labour camp	164	129	140
Collective residence	13,420	5,957	2,663
Others	1,033	811	800
Total	291,750	322,461	366,413

4.1.3 Data for Abu Dhabi Emirate

Two sources of data on housing units for Abu Dhabi Emirate were obtained previously. One data source is a buildings database, which includes data on the location, size, and classification of more than 130,000 buildings (UPC, 2007b). In general, the database does not provide data on individual housing units. For example, the database includes information on more than 8,000 mixed use buildings classified as “commercial/residential,” but provides no data on how many apartments or residential units are represented by those buildings. However, the database does provide information on more than 51,000 buildings that are classified as villas; these data are discussed in more detail in Section 4.2.1. In addition, certain data on apartment buildings were useful in defining other typologies, as described in Section 4.2.3.

The second data source for Abu Dhabi is the *North Island Master Plan*, which includes detailed information on more than 700 buildings in the downtown area of Abu Dhabi (UPC, 2010). The report and underlying data provide floor-by-floor information on building usage, including floor space data for more than 17,000 apartment units. These data are discussed further in Section 4.2.2.

4.2 Typologies

To characterize electricity consumption for residential lighting, the available data on residential housing units were used to define several residential housing unit typologies. These typologies form a systematic classification of housing units, which have common characteristics within a specific typology, but are likely to differ across typologies in terms of lighting characteristics. As a general practice in defining such typologies, there are trade-offs between:

- Making the typologies as specific as possible to ensure each is unique and does not have significant overlap or similarity with any other typology; and
- Limiting the typologies to a manageable number to reflect data constraints and avoid over-complicating the analysis.

For this analysis, a total of 15 typologies were developed: 5 residential apartment typologies, 3 villa typologies, and 7 typologies that correspond to the remaining types of housing units reported in the NBS data and listed in Table 5. To make use of illuminance criteria, the typologies were defined in terms of the types, numbers, and sizes (i.e., floor space) of rooms for each typology. A list of the typologies is provided in **Table 7**, and the following sections describe how the typologies were defined.

Table 7. Residential Housing Unit Typologies

Type of housing unit	Typologies
Flat	Studio apartment, 1-bedroom apartment, 2-bedroom apartment, 3-bedroom apartment, 4-bedroom or larger apartment
Villa	Small villa Medium villa Large villa
Part of Villa	Part of Villa
One Story Building	One Story Building
Public House	Public House
Part of Public House	Part of Public House
Separate Room(s)	Separate Rooms
Arabic House	Arabic House
Others	Others

4.2.1 Villas

The UPC buildings database (see Section 4.1.3) provides the largest data set obtained with information on specific villas. For this reason, the database was used to develop the villa typologies. The following paragraph describes how the typologies were developed.

The UPC database includes data on floor space for more than 51,000 buildings classified as villas. A quick review of the floor space data, which range from 3.3 m^2 to more than 17,000 m^2 of floor space, indicates that not all of the buildings represent entire villas. As a first step, all buildings with less than 100 m^2 of floor space were removed from the data set. This reduced the number of buildings from 51,242 to 42,012 buildings. The data for those remaining buildings were used to develop three villa typologies (small, medium, and large) to better represent the entire population of villas. An exploratory analysis of the data was then performed using floor space percentiles and quartiles to classify the villas based by size. **Table 8** summarizes the results of the analysis. Additional details on the procedures and intermediate results to evaluate the villa data are provided in Appendix I.

Table 8. Summary of Villa Data Size Analysis

Villa size	Number of villas	Percent of total	Floor space range, m^2	Average floor space, m^2
Small	15,292	36.4%	< 418	258
Medium	22,068	52.5%	418 to 1,342	743
Large	4,652	11.1%	> 1,342	1,926
Total	42,012	100%	—	—

4.2.2 Apartments

The data used to develop the apartment typologies were obtained from the Abu Dhabi *North Island Master Plan* and the housing statistics provided on the DSC website. Each of these data sets is described below.

North Island Master Plan (UPC, 2010)

The report and underlying database provide data on more than 700 buildings in the downtown area of Abu Dhabi. Most of the buildings are mixed use commercial and residential structures, in which the lower floors are occupied by shops and commercial offices, and the upper floors have residential apartments and penthouses. The data includes tenant categories (e.g., commercial office, residential apartment), total floor space, and number of units on each floor of each building. For apartments, the database indicates the number of bedrooms, which ranged from one to five per unit. Altogether, data are provided on more than 17,000 apartments.

Although the database did not differentiate between studio apartments and 1-bedrooom apartments, the floor space data indicated several of the apartments were likely to be studios. A plot of the data indicated a breakpoint at about 66 m^2 of floor space, and this value was selected to differentiate between studio and 1-bedroom apartments. **Table 9** summarizes the data on floor space by apartment type.

Table 9. Summary of Data for Abu Dhabi on Apartment Floor Space (UPC, 2010)

Apartment Type	Number	% of Total	Floor Space, m^2		
			Minimum	Maximum	Average
Studio	711	4.1%	42	66	53
1-Bedroom	2,624	15.1%	71	1,433	112
2-Bedroom	6,041	34.9%	40	757	142
3-Bedroom	6,932	40.0%	51	896	184
4-Bedroom	871	5.0%	92	897	245
5-Bedroom	18	0.1%	194	291	216
Penthouse	131	0.8%	61	1,147	232
	17,328	100%	—	—	—

Dubai Statistics Center Data

Information on the DSC website (Table Code GC05-04-09) includes a breakdown of the data from the 2005 census on the number of apartments by number of bedrooms. Although the table does not differentiate between 1-bedroom and studio apartments, another table on the website (Table Code GC05-04-08) provides the total number of rooms per housing unit type, and the data for 1-room apartments were assumed to represent studio apartments. The DSC data also not contain information on floor space. **Table 10** below summarizes the resulting data on apartment sizes.

Table 10. Summary of DSC Data on Apartment Size by Number of Bedrooms

Number of bedrooms	Total Number of Apartments	% of Total
Studio	28,497	20.3%
1	48,356	34.4%
2	55,250	39.3%
3	6,912	4.9%
4	1,146	0.8%
5	137	0.1%
6+	236	0.2%
Total	140,534	100%

When compared to the data in Table 9, there are striking differences in the relative number of studio, 1-bedroom, and 3-bedroom apartments; whereas 1-bedroom and studio apartments comprise about 19% of the apartments based on the Abu Dhabi data, nearly 55% of the apartments in Dubai were either studio or 1-bedroom. On the other hand, 3-bedroom apartments comprised 40% of the total using the Abu Dhabi data, but only 5% of the total in Dubai. The reason for these differences is unknown. Age may be a factor because the data from Abu Dhabi reflect an older part of the city, whereas data from Dubai may represent more recent construction. No data on building age were available for the Dubai apartments. For the Abu Dhabi buildings, the age was unknown for about a third of the buildings, and the age was estimated for the other buildings. According to the estimates, about 68% of the buildings with estimated ages were constructed between 1975 and 1995, and 32% were constructed between 1996 and 2010. Overall, however, any explanation for the difference in size distribution between the apartments in Abu Dhabi and Dubai is speculative.

Because the data for Dubai encompass the entire Emirate, whereas the data for Abu Dhabi represent the historic downtown area of Abu Dhabi City, it was assumed that the data for Dubai are more representative of the UAE. Consequently, the apartment size distribution data for Dubai were used for the baseline assessment.

Recommended Apartment Typology Floor Space and Distribution

Apartment typologies were developed by combining the average floor space data summarized in Table 9 with the distribution of apartments shown in Table 10. A review of the larger apartments found no significant difference in floor space between 4-bedroom apartments, 5-bedroom apartments, and penthouses, so these were grouped as a single typology. **Table 11** summarizes the recommended apartment typology floor space and relative distribution for evaluating lighting usage in the UAE.

Table 11. Recommended Apartment Typologies

Typology	% of Total	Average Floor Space, m^2
Studio	20.3%	53
1-Bedroom	34.4%	112
2-Bedroom	39.3%	142
3-Bedroom	4.9%	184
4-Bedroom Plus	0.8%	243

4.2.3 Other Types of Residential Units

Other than the definitions and numbers of units, no data were obtained on the remaining seven categories of residential units. For this reason, the data on villas and apartments were used to represent each of these categories. The following paragraphs describe how each category is defined for the analysis. Following these descriptions, **Table 12** summarizes how each unit is represented for the analysis.

Part of Villa

This category represents an addition to an existing villa on the same property. It is assumed that such additions are relatively small. As noted above, the villa data in the UPC buildings database included more than 9,200 buildings with less than 100 m^2 in floor space, but classified as villas. In the absence of any other data, these buildings were assumed to represent the *Part of Villa* housing unit category. Based on the UPC data, the average floor space for these buildings is 47 m^2.

One Story Building

This housing unit category appears to refer to individual apartments. For the purposes of estimating lighting, it was assumed each building in this category has the same lighting requirements as a 3-bedroom apartment.

Public House

Based on the definitions provided, this category appears to best match small villas. Therefore, the assumption was made that, for lighting purposes, the housing units in this category are comparable to small villas.

Part of Public House

Because the definition of this category parallels that of *Part of Villa*, it was assumed that lighting usage for this category is comparable to that of *Part of Villa*, described above.

Separate Room(s)

This type of housing unit consists of a single room with neither toilet nor kitchen facilities. For the purpose of estimating lighting, it was assumed that this housing unit was comparable to a bedroom in a 1-bedroom apartment.

Arabic House

This housing unit consists of one-story housing unit. It was assumed that the lighting characteristics are comparable to those of a small villa.

Others

This category consists of various types of temporary and/or labor housing units, such as tents, shacks, cabins, shed, and caravans, which, as a group, are likely to cover a wide range of sizes and floor space. In the absence of any other information on the relative size of these units, it is assumed these housing units are comparable to four 1-bedroom apartments.

Table 12. Representation of Other Residential Housing Unit Typologies for the Analysis

Typology	How Represented for the Analysis
Part of Villa	Equivalent to villa with 47 m^2 of total floor space
One Story Building	Equivalent to 3-bedroom apartment
Public House	Equivalent to small villa
Part of Public House	Equivalent to villa with 47 m^2 of total floor space
Separate Room(s)	Equivalent to bedroom of 1-bedroom apartment
Arabic House	Equivalent to small villa
Others	Equivalent to four 1-bedroom apartments

4.2.4 Estimated Number of Housing Units by Typology in 2011

To determine the number of residential housing units by typology in 2011, the 2005 housing unit data from the NBS website (Table 5) was scaled up using the growth rates developed from the population data (Table 4), with one exception. For the Dubai Emirate, the data from the DSC website for 2010 (Table 6) was scaled up using the growth rate for Dubai, and the housing unit types were matched to those reported in the NBS data. For example, the *Villa Supplement* housing units reported for Dubai were assumed to represent the *Part of Villa* housing units. Finally, the data for villas and apartments for all Emirates were distributed across the villa and apartment typologies using the percentages shown in Tables 8 and 10, respectively. **Table 13** summarizes the estimated number of housing units for 2011 that resulted from these steps.

Table 13. Estimated Number of Housing Units in by Typology in 2011

Type of housing unit	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Studio Apartment	62,777	60,897	42,088	9,287	896	4,757	5,393	186,095
1-Bedroom Apartment	106,524	103,335	71,418	15,760	1,520	8,072	9,152	315,781
2-Bedroom Apartment	121,711	118,067	81,600	18,006	1,737	9,223	10,457	360,801
3-Bedroom Apartment	15,227	14,771	10,208	2,253	217	1,154	1,308	45,138
4+-Bedroom Apartment	3,346	3,246	2,243	495	48	254	287	9,919
Small villa	18,331	25,345	7,560	2,394	962	8,037	2,927	65,556
Medium villa	26,439	36,555	10,904	3,453	1,388	11,591	4,222	94,552
Large villa	5,590	7,729	2,305	730	293	2,451	893	19,991
Part of Villa	11,257	959	1,528	598	42	1,305	327	16,016
One Story Building	52,389	—	9,155	3,336	2,467	18,093	13,060	98,500
Public House	69,038	2,850	17,211	3,337	4,944	27,939	21,287	146,606
Part of Public House	38,626	—	2,299	771	234	1,090	2,083	45,103
Separate Rooms	46,705	2,630	19,632	4,356	1,794	9,425	8,180	92,722
Arabic House	0	14,732	19,436	8,275	10,593	57,646	9,993	120,675
Others	57,904	1,006	4,330	1,426	1,150	6,567	2,887	75,270
Total	635,864	392,122	301,917	74,477	28,285	167,604	92,456	1,692,725

4.3 Housing Unit Layout by Room Type

As discussed previously, estimating lighting electricity consumption based on illuminance requires information on floor space and type of usage (i.e., room type). This section describes the process used to determine typical residential housing unit layouts or floor plans for this purpose. Since all residential housing typologies are represented in the analysis as either apartments or villas, this section discusses representative layouts for apartments and villas only.

4.3.1 Apartment Typology Layouts

Because no data were available on apartment layouts, the data on floor space presented in Table 4 were used along with general assumptions on the types, numbers, and dimensions of rooms in a typical apartment. The assumptions were based on general knowledge of apartment layouts in the U.S., with respect to the relative sizes of kitchens and bedrooms. For washrooms, data on villa floor plans (see Section 4.3.2) were reviewed and it was assumed that apartment washrooms would generally be comparable to the smaller sizes found in villas.

It was also assumed that walls comprised approximately 5% of the gross floor space of an apartment, which also is typical for residential construction, based on U.S. and the villa floor plans discussed in Section 4.3.2. The dimensions of each room were then adjusted using an iterative approach until total floor space for all rooms was equivalent to the floor space defined for each apartment typology. **Tables 14 through 18** show the resulting layouts used for the analysis.

Table 14. Studio Apartment Layout

Room	Dimensions, m		Number	Floor Space, m^2
	Length	Width		
Foyer	1.2	1.2	1	1.4
Kitchen	4.0	3.0	1	12.0
Bedroom	5.0	4.0	1	20.0
Washroom	2.3	2.0	1	4.6
Dining room	4.0	3.0	1	12.0
Subtotal	—	—	—	50.0
Allowance for walls (5%)	—	—	—	2.6
Total	—	—	—	52.7

Table 15. 1-Bedroom Apartment Layout

Room	Dimensions, m		Number	Floor Space, m^2
	Length	Width		
Foyer	2.0	1.2	1	2.4
Corridor	7.0	1.2	1	8.4
Kitchen	5.0	4.0	1	20.0
Dining room	5.0	4.5	1	22.5
Living room	5.0	4.5	1	22.5
Washroom	2.3	2.0	1	4.6
Bedroom	6.0	4.3	1	25.8
Subtotal	—	—	—	106.2
Allowance for walls (5%)	—	—	—	5.6
Total	—	—	—	111.8

Table 16. 2-Bedroom Apartment Layout

Room	Dimensions, m		Number	Floor Space, m^2
	Length	Width		
Foyer	2.0	1.2	1	2.4
Corridor	10.0	1.2	1	12.0
Kitchen	5.0	4.0	1	20.0
Dining room	5.0	4.5	1	22.5
Living room	5.0	4.0	1	20.0
Washroom	2.3	2.0	2	9.2
Bedroom	5.0	4.4	2	44.0
Utility room	3.0	1.6	1	4.8
Subtotal	—	—	—	134.9
Allowance for walls (5%)	—	—	—	7.1
Total	—	—	—	142.0

Table 17. 3-Bedroom Apartment Layout

Room	Dimensions, m		Number	Floor Space, m^2
	Length	Width		
Foyer	2.0	1.2	1	2.4
Corridor	14.0	1.2	1	16.8
Kitchen	5.0	4.0	1	20.0
Dining room	5.0	4.0	1	20.0
Living room	6.0	4.0	1	24.0
Washroom	2.4	2.3	2	11.0
Bedroom	6.0	4.2	3	75.6
Utility room	3.0	1.6	1	4.8
Subtotal	—	—	—	174.6
Allowance for walls (5%)	—	—	—	9.2
Total	—	—	—	183.8

Table 18. 4-Bedroom and Larger Apartment Layout

Room	Dimensions, m		Number	Floor Space, m^2
	Length	Width		
Foyer	2.3	1.2	1	2.8
Corridor	18.0	1.2	1	21.6
Kitchen	5.5	5.0	1	27.5
Dining room	6.0	4.5	1	27.0
Living room	6.0	5.0	1	30.0
Washroom	2.4	2.3	3	16.6
Bedroom	6.0	4.2	4	100.8
Utility room	3.0	1.6	1	4.8
Subtotal	—	—	—	231.0
Allowance for walls (5%)	—	—	—	12.2
Total	—	—	—	243.2

4.3.2 Villa Typology Layouts

To identify representative layouts of the villa typologies, an internet search was performed. Floor plans for villas were found on several websites for large developments in Dubai and Abu Dhabi. Several such floor plans were downloaded and reviewed in an effort to identify typical villa layouts that were representative of the three villa typologies. **Figures 3 and 4** are examples of two of the villa floor plans reviewed.

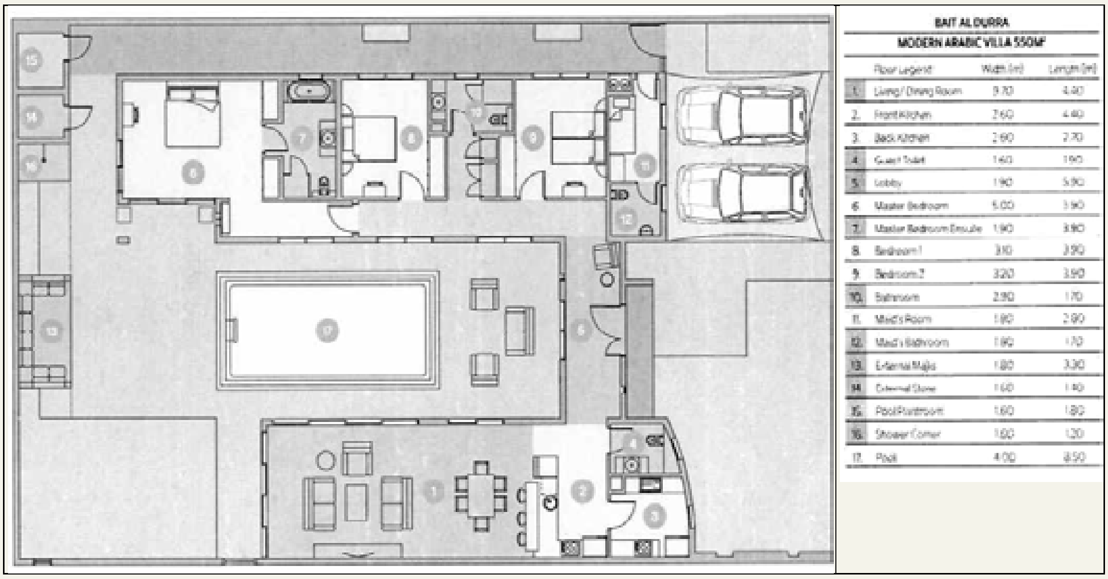

Figure 3. Example of Villa Floor Plan (DAB, 2009)

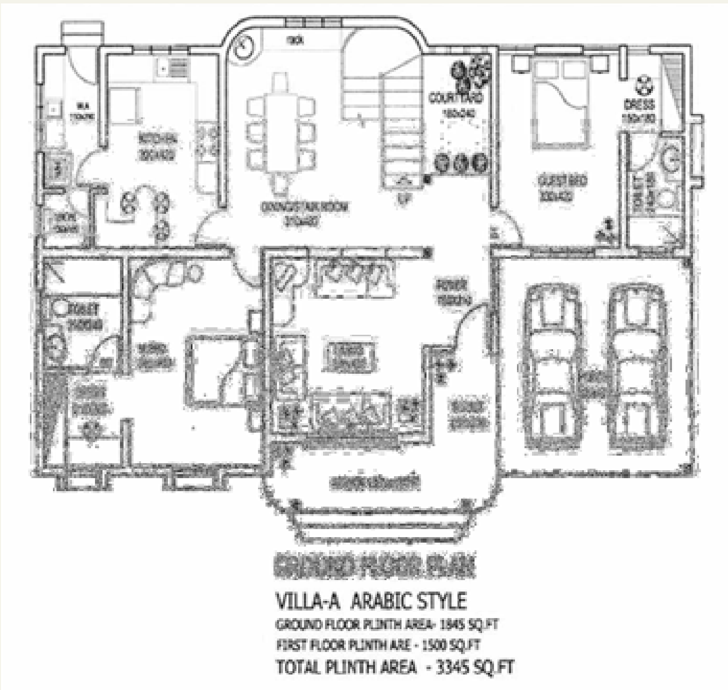

Figure 4. Example of Villa Floor Plan (SRK, 2012)

Although there was extensive variation in room sizes, types, and numbers, only a few of the floor plans provided actual room dimensions. In addition, total floor space was generally in the range of 200 to 600 m^2, which would be representative of the small villa typology (258 m^2), and possibly the medium villa typology (743 m^2), but not for the large villa typology (1,926 m^2). Consequently, an alternative approach was needed to determine villa typology layouts.

Several of the floor plans that provided dimensions (in the range of 300 to 500 m^2) were compared to determine the relative floor space for each type of room as a percentage of total floor space. The percentages were then used adjusted up or down to account for differences in villa size for the three typologies. For example, it would be expected that large villas would have a higher percentage of floor space for bedrooms and washrooms and a smaller percentage of overall floor space for kitchens or dining rooms. The adjusted percentages were then applied to the values for total floor space for each of the three villa typologies shown in Table 8. **Table 19** shows the resulting layouts.

Table 19. Villa Typology Layouts

Room	Small Villa		Medium Villa		Large Villa	
	% of Total	Floor space, m^2	% of Total	Floor space, m^2	% of Total	Floor space, m^2
Foyer	2.0%	5.2	1.7%	13.0	1.4%	27.0
Corridor	7.0%	18.1	7.0%	52.2	7.0%	134.8
Kitchen	11.0%	28.4	9.5%	70.4	7.2%	138.7
Dining room	12.4%	32.0	11.3%	83.6	9.2%	177.2
Living room	8.4%	21.7	8.4%	62.5	8.4%	161.8
Family room	9.8%	25.3	9.8%	72.9	9.8%	188.7
Washroom	10.0%	25.8	12.2%	90.9	15.0%	288.9
Bedroom	23.0%	59.3	25.7%	191.2	29.7%	572.0
Utility room	1.3%	3.4	1.3%	9.7	1.3%	25.0
Garage	10.0%	25.8	8.0%	59.4	6.0%	115.6
Walls	5.0%	12.9	5.0%	37.2	5.0%	96.3
Total	100.0%	258	100.0%	743	100.0%	1,926

5. Lighting Requirements and Usage

This section provides an overview of the lighting requirements reviewed and the specific criteria used for the baseline assessment. Section 5.1 provides a summary of existing codes and standards that address lighting in the UAE. Section 5.2 provides a discussion of recommended illuminance targets, which specify minimum lighting requirements as a function of floor space and type of activity being performed. Section 5.3 presents a summary of data on daily (or annual) residential lighting usage by room type.

5.1 UAE Lighting Codes and Standards

In addition to data requests to specific government agencies and stakeholder organizations, a general search was conducted for existing buildings codes and other standards that apply to lighting in the UAE. This effort yielded several codes and standards that apply specifically to the Dubai and Abu Dhabi Emirates. In terms of lighting, the codes and standards focus on the commercial sector and do not generally address residential lighting in much detail. Furthermore, the existing regulations do not provide many limitations on what can be used for residential lighting in the UAE. The following paragraphs provide a brief summary of each. Additional details on standards for Dubai Emirate are provided in Appendix II, and Appendix III provides additional information on standards that were reviewed for the Abu Dhabi Emirate.

5.1.1 Dubai Emirate Codes and Standards

For Dubai Emirate, two documents were obtained that specify codes and standards: *Building Code Regulations and Construction Specifications*, and *Green Building Regulations and Specifications in the Emirate of Dubai.*

Building Code Regulations and Construction Specifications (DM, 2004)

The *Building Code Regulations and Construction Specifications* specify the codes and standards for new building construction in Dubai. Other than Articles 12, 14, and 21, which address the minimum requirements for natural lighting, this document does not address requirements for residential lighting.

Green Building Regulations and Specifications in the Emirate of Dubai (DM, 2010)

This standard sets forth regulations "…to improve the performance of buildings in Dubai by reducing the consumption of energy, water and materials, improving public health, safety and general welfare and by enhancing the planning, design, construction and operation of buildings to create an excellent city that provides the essence of success and comfort of living." Section 502 of the Green Building Regulations addresses lighting requirements in terms of lighting power density (LPD). LPD criteria specify the maximum allowable energy use for lighting as a function of floor space or similar metric. For example, an LPD of 17 watts per square meter (W/m^2) means that the electric power used for lighting the designated area or room can be no greater than 17 W/m^2 of lighted floor space. Section 502.24 of the Green Building Regulations includes LPD criteria for interior lighting of commercial buildings and refers to ASHRAE 90.1-2007 for LPD criteria for interior lighting in other types of buildings. However, the referenced table from ASHRAE 90.1 has limited applicability to residential lighting, other than a general requirement for multifamily buildings (7.5W/m^2).

Section 502.05 of the Green Building Regulations specifies LPD criteria for exterior lighting, but they also are of limited use for residential applications. Finally, Section 303.01 addresses exterior light pollution and controls to ensure that exterior lighting minimizes lighting of the night sky and the use of exterior lighting during daylight hours.

5.1.2 Abu Dhabi Emirate Codes and Standards

For Abu Dhabi Emirate, several documents were reviewed that specify codes, standards, and guidelines for building design, construction, and operation. **Table 20** includes a list of the codes and standards reviewed. Most of the listed standards do not specify criteria for residential lighting, other than for common areas, such as elevators and stairways, exterior lighting, and natural lighting. The following paragraphs summarize the specific requirements that apply to residential lighting. Additional details are provided in Appendix III.

Table 20. Summary of Abu Dhabi Emirate Codes and Standards Reviewed

Code/Standard	Description/Purpose
Accessible and Usable Buildings and Facilities (Abu Dhabi/ICC A117.1-2009)	Building criteria to ensure that people with physical disabilities can independently get to, enter, and use a site, facility, building, or element.
Abu Dhabi International Building Code	Minimum requirements for structural strength, egress, stability, sanitation, adequate light/ventilation, energy conservation, and safety of buildings.
Abu Dhabi International Energy Conservation Code	Design and construction of residential and commercial buildings for the effective use of energy.
Abu Dhabi International Fuel Gas Code	Standards for the installation of fuel-gas piping systems, fuel gas appliances, gaseous hydrogen systems, and related accessories.
Abu Dhabi International Mechanical Code	Standards for the design, installation, maintenance, alteration, and inspection of mechanical systems and equipment involved in controlling environmental conditions inside buildings.
Abu Dhabi International Property Maintenance Code	Standards for existing residential and non-residential structures and premises; provides minimum requirements for light, ventilation, space, heating, sanitation, and safety.
Estidama Pearl Building Rating System (PBRS) – RE-R1 Energy Prescriptive Pathway	Based on selected requirements from the Abu Dhabi International Energy Conservation Code; provides a summary of the requirements relating to envelope, systems, lighting, and renewables.
The Pearl Rating System for Estidama – Building Rating System Design and Construction	Requirements to address the sustainability of a given development throughout its lifecycle from design through construction to operation; design guidance and detailed requirements for rating a project's potential performance in relation to the four pillars of Estidama.

International Energy Conservation Code (DMA, 2011a)

The *International Energy Conservation Code* (IECC) applies to new building construction, and to additions, alterations, renovations, and repairs to existing buildings with some exceptions. In terms of lighting, the standards do not apply to:

- Alterations that replace less than 50% of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.
- Alterations that replace only the bulb and ballast within the existing luminaires in a space, provided that the alteration does not increase the installed interior lighting power.

Section 404.1 of the IECC requires a minimum of 50% of lamps in permanently installed luminaires to be high efficacy, which is defined in Section 202 as any of the following:

- Compact fluorescent lamps
- T-8 or smaller diameter linear fluorescent lamps, or
- Lamps with a minimum efficacy of:
  - 60 lumens per watt for lamps over 40 watts,
  - 50 lumens per watt for lamps over 15 watts to 40 watts, and
  - 40 lumens per watt for lamps 15 watts or less.

These efficacies basically restrict incandescent and halogen lamps from being installed in 50% or more of built-in luminaires. However, plug-in lamps and luminaires have no such restrictions. The IECC also specifies LPD criteria, which appear to be comparable to those covered by the Dubai's

Green Building Regulations. As noted above, the criteria apply largely to commercial buildings, but do specify a general requirement for multifamily buildings of 7.5W/m^2.

Estidama Pearl Building Rating System (UPC, 2011)

The Estidama Pearl Building Rating System specifies LPD criteria for commercial buildings and applications. The criteria are similar to, but slightly more stringent than, the criteria specified in Dubai's Green Building Regulations (see above). For example, for multifamily buildings, the Pearl Rating System has a general requirement of 6.8 W/m^2, compared to 7.5 W/m^2 for the Green Building Regulations. The Pearl program also specifies LPD criteria for exterior lighting. A list of the relevant values is included in Appendix III.

International Property Maintenance Code (DMA, 2011b)

In addition to requirements for natural lighting, the International Property Maintenance Code (IPMC) includes requirements for the lighting of common halls and stairways in residential housing units, other than one- and two-story buildings. For these housing units, the IPMC requires continuous lighting using at least one 60W incandescent lamp, or equivalent, for every 19 m^2 of floor space and at least one lamp every 9.1 meters of hallway.

Accessible and Usable Buildings and Facilities Code (DMA, 2009)

This standard specifies requirements for elevator and stairwell illumination that apply to all buildings. Elevators are required to have illuminance of at least 54 lux at the elevator controls, platform, threshold, and landing. Stairwell illumination must be at least 108 lux at the center of tread surface and on landing surfaces within 0.61 m of step nosings.

5.1.3 Implications of Existing Codes and Standards on Current Lighting

As noted above, the existing codes and standards reviewed focus more on commercial lighting, and the codes that do apply to residential lighting place pertain largely to common areas (e.g., corridors, stairways, elevators) and do not significantly restrict the type of lighting that can be used within residences. The LPD criteria include a general limit on multi-family residential units, but it is unclear how these would apply or would be enforced in individual residential apartments. The IECC code requires the use of high efficiency lighting, but applies to only 50% of built-in luminaires. In conclusion, it does not appear that the existing codes and standards, as currently codified, will ensure the use of energy efficient lighting throughout new and existing construction in the UAE.

5.1.4 Summary of Codes and Standards for Other Countries

North America

Building codes in the United States and Canada are established by state with the minimum Federal requirement of 75% of all lamps in permanently installed fixtures being of high efficacy, as outlined in **Table 21** (U.S. DOE, 2012b). Incandescent bulbs do not currently meet these energy-efficiency requirements, limiting bulbs to CFLs, T-8 or smaller diameter fluorescent tubes, or other energy-efficient products.

Table 21. Criteria for High Efficacy Lamps in North America

Lamp Rating, W	Minimum Efficiency, lm/W	Reference
≤ 5	30	CEC, 2008
> 5 to ≤15	40	BECP, 2009
>15 to ≤ 40	50	BECP, 2009
> 40	60	BECP, 2009

Currently, California has the most stringent new residential building-code requirements in North America (CEC, 2008). In addition to requiring all permanent fixtures to use state-of-the-art fluorescent lighting, the following lighting standards apply:

Internal Lighting

- Kitchens: at least 50% of installed lighting wattage must have high efficacy.
- Internal cabinets: No more than 20 W per linear foot of illuminated cabinet may be permanently installed inside cabinets.
- Bathrooms, garages, utility, closets (>70 square feet), and laundry rooms: 100% of the permanent lighting must have high-efficacy lamps or be controlled by an occupancy sensor.
- All other rooms: 100% of the hard-wired lighting must have high-efficacy lamps or be controlled by a manual-on occupancy sensor or dimmer.
- Ballasts for residential recessed luminaires: must have a minimum rated life of 30,000 hours and have a ballast factor of not less than 0.90 or 0.85 for non-dimming ballasts and dimming ballasts, respectively.
- Electronic ballasts: Fluorescent lamps rated 13 W or greater shall have electronic ballasts with an output frequency no less than 20kHz.
- Night lights: Permanently installed night lights shall either contain only high-efficacy lamps without a line-voltage socket or line-voltage lamp holder, or shall be rated to consume no more than 5W and not contain a medium screw-base socket.

External Lighting

- Outdoor Lighting: 100% of all permanently mounted luminaires of residential buildings and other buildings on the same lot must be high efficacy, except if low-efficacy luminaires are controlled by a manual on/off switch, a motion sensor that cannot be overridden for more than 6 hours, and one of the following, none of which can have an override or bypass system that would allow the luminaire to be always on
  a. Photocontrol
  b. Astronomical time clock
  c. Energy management control system (EMCS)

Europe (ZCH, 2011)

The EU Ecodesign Directive 2005/32/EC as amended by Directive 2009/125/EC provides requirements for fluorescent lamps without integrated ballast, high-intensity discharge lamps, and ballasts and luminaires able to operate such lamps. These requirements effectively ban the sale of non-compliant products (i.e. incandescent lamps) and forces manufacturers to produce more energy-efficient lighting products.

Under the European Union’s Energy Performance in Buildings Directive (EPBD 2002/91/EC) as updated in Directive 2010/31/EU, EU member states are required to implement regulations that will reduce the energy consumption of the EU by 20% by 2020. Those regulations pertaining to lighting must

- Have mandatory minimum energy-efficiency standards for new buildings and renovations of all buildings.
- Use a calculation of the energy performance of buildings of all types, including residential, to determine cost-optimal levels of minimum energy performance requirements. The calculation method must include all factors influencing energy consumption, including lighting.

For example, the UK domestic building regulation (2010) uses a residential building energy performance standard based on a target CO_2 emissions rate for heating, hot water, and lighting. The Domestic Building Services Compliance Guide (DCLG, 2011) specifies that the EU Directive can be attained by installing:

- At least 75% of internal light fittings (>5W) should be fixed luminaires using efficient lamps (>45 lm/W efficacy) and a total output greater than 400 lm.
- No more than 100 W per light fitting for external lighting, with automatic shut-off when unoccupied and upon daylight, or sockets requiring lamps with >45 lm/W efficacy, automatic shutoff upon daylight, and manually controlled light fittings.

Australia/New Zealand

Harmonized lighting codes do not apply to residential buildings (ABCB, 2009; DBH, 2011).

China

The Ministry of Construction adopted a building energy performance standard (#GB 50034-2004) for residential lighting in 2004 requiring a maximum LPD threshold of 7 W/m^2 (IEA, 2006). In 2008, the Chinese government launched a 3-year Financial Subsidies Fund of Promoting High Efficient Lighting Products, where residents received a 50% discount on each high-efficiency lighting product purchased (CSC, 2009).

5.2 Recommended Illuminance Targets

Illuminance criteria or targets are used to specify the minimum recommended requirements for lighting systems. Historically, illuminance criteria have focused on the commercial and industrial sectors to help ensure adequate lighting for workers to fulfill the requirements of the job in a safe manner, and on the educational sector to ensure adequate lighting for reading, writing, and related activities. Although building codes and standards for industrial and commercial applications often specify illuminance levels, there is a serious lack of uniformity in the criteria. A survey of illuminance criteria from 19 countries found recommended levels varying by 10- to 30-fold for certain activities in the commercial sector, 25- and 40-fold for activities in the industrial sector, and 6- to 10-fold in the educational sector (IEA, 2006).

For this assessment, *The Lighting Handbook* (IES, 2011), hereafter referred to as the *Handbook*, was used as the source for illuminance criteria for residential housing units. This publication provides one of the most comprehensive sets of illuminance criteria available. More importantly, and unlike many codes and standards, it provides detailed criteria for residential lighting applications. The Handbook classifies each common activity on a room-by-room basis according to a set of 25 categories that range from large-scale physical tasks that require little lighting, such as building entryways, to extremely minute or life-sustaining tasks that require intense lighting, such as hospital operating rooms. Illuminance criteria are specified (in units of lux) for horizontal targets (e.g., floors in corridors, or table tops in dining rooms) and vertical targets (e.g., 1.2 meters above the floor in dining rooms). The Handbook also specifies illuminance criteria according to three age ranges: persons younger than 25 years, persons 25 to 65 years, and persons older than 65 years.

Table 22 provides a summary of the illuminance criteria specified in the Handbook for residential interiors. The table provides horizontal and vertical criteria for the 25-to-65 year age range for 16 rooms and 33 types of activities or locations within a room. (Note: Table 22 does not list all of the residential illuminance criteria included in the Handbook, but is meant to provide an idea of the requirements for rooms and activities that are relevant to this baseline assessment.)

The illuminance criteria shown in Table 22 were consolidated and simplified for each type of room to produce general room illuminance levels for this baseline assessment. Two additional adjustments were made to the criteria:

1. Since illuminance criteria are meant to provide minimum recommended requirements, the actual lighting installed or used is typically greater than would be determined by simply multiplying illuminance by floor space. For this reason, the illuminance criteria were increased by a factor of 25%, which is a typical value.
2. Consideration must also be given to losses caused by luminaires. A typical value of 30% (IEA, 2006) was applied to the criteria to account for such losses.

As a cross-check, the illuminance levels were then applied to the layouts for the 2-bedroom apartment, 3-bedroom apartment, and small villa to estimate the total number of lamps required, assuming the equivalent of 75W incandescent lamps. Those lamp totals were compared to data for the U.S. and the EU for average number of lamps per residential unit. **Table 23** summarizes the data for the U.S. and shows the average number of lamps by room type for four types of residential housing units. The EU study used an overall average of 24.3 lamps per household (VITO, 2009), but a breakdown of number of lamps by residence type and room was not provided. Based on those comparisons, minor adjustments were made to the illuminance levels. **Table 24** summarizes the final illuminance criteria used for the baseline assessment.

Table 22. Recommended Minimum Illuminance (IES, 2011)

Type of Room	Part of room or type of activity	Recommended Illuminance Targets, lux	
		Horizontal	Vertical
Washroom	Showers, tubs	50	20
	Toilets, bidets	100	30
	Vanities – Casual inspection	200	200
	Vanities – Grooming	300	400
Bedroom	General (dressing)	50	30
	Reading	200	100
Corridors	Independent passageways	30	6
Closets	Non-walk-in	100	40
	Walk-in	300	100
Dining	Formal	50	20
	Informal	100	40
	Study use	200	50
Dressing Room	General	100	—
	Full-length mirror	—	200
Family Room	General	100	40
Foyer	Day	100	30
Garage	General	50	50
	Vehicle maintenance	200	100
	Work Bench – manual tools	400	200
	Work Bench – power tools	500	500
Kitchen	General	50	20
	Breakfast area	200	50
	Cooktops	300	50
	Preparation counters	500	75
	Sinks	300	50
Laundry	Ironing, washing, drying	200	50
Living Room	General	30	30

(continued)

Table 22. Recommended Minimum Illuminance (IES, 2011) (continued)

Type of Room	Part of room or type of activity	Recommended Illuminance Targets, lux	
Office	Occasional work	200	30
	Continuous work	400	75
Reading and Writing	Bed headboard	200	100
	Casual chair	200	50
	Desk	400	75
Steps/Stairs	General	50	—
Storage	Frequent use	50	20

Table 23. Average Number of Lamps per Residence (U.S. DOE, 2012a)

Room/Location	No. of Lamps				
	Single Family Detached	Single Family Attached	Multifamily	Mobile Home	Average
Basement(s)	1.5	1.8	0.2	0.2	1.2
Bathroom(s)	10.5	8.6	5.1	7.1	8.9
Bedroom(s)	9.7	8.0	4.4	6.6	8.2
Closet(s)	1.7	1.1	0.7	0.7	1.4
Dining Room(s)	4.1	3.6	1.7	2.5	3.4
Exterior(s)	5.4	2.7	1.1	2.9	4.1
Garage(s)	4.0	1.4	0.5	0.6	2.9
Hall(s)	5.6	4.7	2.2	1.4	4.5
Kitchen(s)	7.2	6.8	4.4	4.4	6.4
Laundry / Utility Room(s)	1.4	0.7	0.2	1.0	1.1
Living / Family Room(s)	7.5	6.0	4.1	5.6	6.5
Office(s)	1.7	0.9	0.5	0.2	1.3
Other	2.0	2.0	0.3	1.3	1.6
TOTAL	62.4	48.0	25.4	34.6	51.4

Table 24. Illuminance Criteria Used for Baseline Assessment

Room	Illuminance, lux			
	Recommended Minimum[a]	Increased by 25%	Luminaire Loss[b]	Net
Foyer	100	125	30%	179
Corridor	80	100	30%	143
Kitchen	125	156	30%	223
Dining room	75	94	30%	134
Family room	125	156	30%	223
Living room	100	125	30%	179
Washroom	250	313	30%	446
Bedroom	80	100	30%	143
Utility room	150	188	30%	268
Garage	100	125	30%	179

[a] IES, 2011.

[b] IEA, 2006.

5.3 *Lighting Usage Data*

With illuminance criteria and floor space data, lighting requirements can be estimated in units of lumens. In order to convert those lighting requirements to daily or annual electricity consumption, values are also needed for usage rates (e.g., hours per day [hr/day], hours per year [hr/yr]). The following paragraphs describe the available data on residential lighting usage data by room type.

5.3.1 UAE Studies and Data on Lighting Usage Rates

Three sources of information were obtained that provide data on lighting usage rates for the residential sector in the UAE. One study, *Analysis of the Impact of Converting All Incandescent Light Bulbs to Energy Efficient Lights in the Emirate of Abu Dhabi* (Hara Inc., 2009) estimates the energy savings that would result if more efficient lighting were installed in a residential buildings, street lights, and shopping malls. Electricity usage and savings were estimated for five types of residential units: palaces, 6-bedroom residences, 4-bedroom residences, 2-bedroom apartments, and 1-bedroom apartments. **Table 25** summarizes the usage rates assumed. The basis for these usage rates was not provided in the report.

Table 25. Estimated Residential Lighting Usage Rates (Hara Inc., 2009)

Room	Lighting Usage, hr/day				
	Palace	6-Bedroom Residence	4-Bedroom Residence	2-Bedroom Flat	1-Bedroom Flat
Bedrooms	1	1	2	1	1
Kitchen	16	16	16	6	6
Bathrooms	2	2	2	1	1
Dining room	2	2	2	2	—
Living room	2	2	2	4	—
Family room	16	16	16	—	—
Security Fence	12	12	12	—	—
Garage	2	2	2	—	—
Hall	12	12	12	2	2

The second document is a submittal to the Clean Development Mechanism (CDM) Program for the *Dubai CFL Project*, which will distribute 705,000 CFL lamps to residents in two densely populated areas of Dubai (UNFCCC, 2011). Participants can trade up to six incandescent lamps per household for comparable CFLs free of charge. To estimate the electricity savings for the project, it was assumed that all lamps are operated 3.5 hr/day, regardless of location. The basis for the assumption was not provided in the project document.

The third source of information on residential lighting use is from an informal survey ESMA conducted with its staff in 2012. ESMA collected lighting usage information on 42 residences from a combination of National and non-National households. A summary of the information by room type is presented in **Table 26**. As shown, the lighting usage hours per day are on average 7.5, which is higher than the previously mentioned studies.

Table 26. ESMA Survey of Residential Lighting Usage Rates

Room	Average Usage (hours/day)
Bedrooms	7.56
Bathrooms	4.52
Hall or Staircase	8.32
Living Room	7.88
Kitchen	7.06
Main Gate	8.00
Main Entrance	7.74
Wall Lights	8.82
Back Door	6.24
Garage	8.59
Villa Wall Lights	9.24
Total Average	**7.50**

One explanation for the relatively high usage rates is that the ESMA survey did not account for the possibility that not all the lamps in a room are on at any given time. For example, a kitchen may have a total of 20 to 30 lamps, but only about half of them may be on at any given time. Thus, if lights are on the kitchen for 6 hours, this translates into 3 hours when applied to the full set of lamps. The international studies that follow are based on actual metered usage and are able to capture these factors.

5.3.2 European Union Study to Develop Residential Lighting Standards

Table 27 summarizes the data compiled in the process of developing the domestic lighting standards for the EU (VITO, 2009). Data were compiled from six countries on annual lighting usage in hours per year (hr/yr) for six categories of rooms: kitchen, dining room/living room, sleeping room, bathroom, home office, and entrance/hall. Annual usage is provided according to the lamps used most often. For example, for France, the kitchen lamp used most often is operated an average of 736 hr/yr; the kitchen lamp used second most often is operated an average of 301 hr/yr. The data in Table 27 represent lighting usage for all lighting sources, regardless of lamp type. The study also reports separately the average usage by lamp type, regardless of location or room (not included in Table 27).

Table 27. Summary of Daily Lighting Usage by Country (VITO, 2009)

Room	No.*	Country					Average Usage	
		Denmark	France	Greece	Italy	Portugal	hr/yr	hr/day
Kitchen	1	1,144	736	1,044	1,150	1,022	1,019	2.79
	2	610	301	349	488	—	437	1.20
	3	410	—	—	—	—	410	1.12
Dining Room Living Room	1	1,427	757	801	683	1,122	958	2.62
	2	866	352	470	316	553	511	1.40
	3	533	250	—	189	—	324	0.89
	4	421	—	—	—	—	421	1.15
Sleeping Room	1	711	432	608	414	452	523	1.43
	2	320	226	323	148	368	277	0.76
	3	194	162	—	—	—	178	0.49
	4	161	—	—	—	—	161	0.44
Bathroom	1	681	334	765	458	594	566	1.55
	2	236	185	246	231	—	225	0.62
	3	—	88	—	—	—	88	0.24
Home office	1	603	589	—	—	—	596	1.63
	2	348	—	—	—	—	348	0.95
Entrance/ hall	1	878	389	800	337	773	635	1.74
	2	364	162	346	—	—	291	0.80
	3	—	145	—	—	—	145	0.40

* Indicates usage by lamp. For example, in Denmark, the kitchen lamp used most often (No. 1) is used an average of 1,144 hr/yr; the kitchen lamp used second most often (No. 2) is used an average of 610 hr/yr.

5.3.3 U.S. Department of Energy Study

Table 28 summarizes the data from a study performed for the U.S., Department of Energy (U.S. DOE, 2012a). Data on daily lighting usage were compiled for 12 types of rooms. Usage rates were collected using lighting logging and recording devices and thus eliminated the potential problems and uncertainty associated with residents estimating or regularly recording how many hours each light was used on a daily basis. The data also represent a more comprehensive characterization of residential lighting because usage rates are reported for four types of residential housing units: single family detached, single family attached, multi-family, and mobile home.

Table 28. U.S. Department of Energy Data on Daily Lighting Usage (U.S. DOE, 2012a)

Room	Average Daily Usage, hr/day				
	Single Family Detached	Single Family Attached	Multi-family	Mobile Home	Average
Basement	1.62	1.70	1.35	1.89	1.62
Washroom	1.57	1.56	1.56	1.60	1.57
Bedroom	1.58	1.57	1.58	1.59	1.58
Closet	1.39	1.36	1.33	1.37	1.38
Dining Room	1.92	1.92	1.91	1.90	1.92
Exterior	2.62	2.66	2.69	2.62	2.63
Garage	1.52	1.50	1.55	1.55	1.52
Hallway	1.46	1.46	1.47	1.47	1.46

(continued)

Table 28. U.S. Department of Energy Data on Daily Lighting Usage (U.S. DOE, 2012a) (continued)

Room	Average Daily Usage, hr/day				
	Single Family Detached	Single Family Attached	Multi-family	Mobile Home	Average
Kitchen	2.34	2.30	2.33	2.35	2.34
Utility room	1.52	1.44	1.33	1.49	1.51
Living room	2.01	2.03	2.04	2.09	2.02
Office	1.85	1.84	1.77	1.84	1.84
Other / Unknown	0.99	1.01	0.90	0.93	0.98
Average	1.80	1.78	1.82	1.85	1.80

5.3.4 Selection of Lighting Usage Rates for Baseline Assessment

A comparison of the usage rates described above shows very wide ranges. The data from the EU and U.S. DOE studies are consistent in that both show average usage rates between 1 and 3 hr/day for the various rooms in a residence. Although the rates may appear to underestimate actual usage, it should be noted that the rates apply to every lamp in a specified room. For example, for kitchen lamps in single-family detached homes, the U.S. DOE study reports an average of 7.19 lamps with an average usage rate of 2.34 hr/day, which amounts to 16.8 hr/day of total lighting. When put into this context, the usage rates seem more reasonable.

The EU data (summarized in Table 27) show only average usage rates for two to four lamps per room. It is unclear if those data include all of the lamps or only a selection of lamps (e.g., the two to four lamps with the highest usage rates), so a direct comparison of U.S. and EU data is not possible. The Hara Report, on the other hand, presents some usage rates that appear to be very high (e.g., 16 hr/day per lamp in kitchens and family rooms) and does not provide the basis for the rates. The across-the-board estimate of 3.5 hr/day used in the CDM project document for Dubai also provides no basis for the rate. The ESMA survey was self-reported and did not account for partial lighting usage.

As described above, the U.S. DOE study provides the most comprehensive data on residential lighting usage. It is recognized that these rates represent lighting usage in the US, and lighting usage in the residential sector of the UAE could be significantly different. However, the DOE study data appear to be the best available at the present time because they apply to all lamps within a room, include data for a broader set of room types, and differentiate between housing unit type. For this reason, the usage data summarized in Table 28 were used for the baseline assessment, as follows:

- Usage rates for single family detached housing units were used to represent the lighting usage for villas and comparable housing unit typologies (part of villa, public house, part of public house, and Arabic house); and
- Usage rates for multi-family housing units were used to estimate lighting usage for the other residential housing unit typologies (apartment, one story building, separate room, others).

6. Lamp Technologies

As noted in Section 2.1, lamp technologies commonly used for interior lighting in the residential sector include incandescent, CFL, linear fluorescent, halogen, and LED. For exterior lighting, in addition to these five technologies, HID lamps are also used. Section 6.1 briefly describes each of these lamp technologies, and Section 6.2 discusses the efficiency of each. The distribution of lamp technologies used for the baseline assessment is discussed in Section 6.3, and Section 6.4 describes the procedure used to estimate number of lamps by residential typology.

6.1 Technologies Used in Residential Sector

6.1.1 Incandescent

Incandescent lamps are a type of non-discharge lamp and are also referred to as general lighting service (GLS) lamps. They include a wire filament, typically of tungsten, encased in a glass bulb. The filament heats up and emits light when electric current is passed through it. Historically, incandescent lamps have been the most common type of lamp used for residential lighting.

6.1.2 Compact fluorescent (CFL)

Compact fluorescent lamps are a type of gas discharge lamp that produces light when an electric current is conducted through mercury vapor. The electric current excites mercury atoms that cause the phosphor coating on the inside of the lamp to fluoresce and produce visible light. CFL lamps, which typically are spiral or U-shaped, are significantly more efficient than the incandescent lamps they are designed to replace.

6.1.3 Linear fluorescent

Linear fluorescent lamps, the traditional tube lamps that have been used for decades, operate on the same principle as CFLs. Linear fluorescent lamps are among the most efficient type of lamp technology available.

6.1.4 Halogen

Halogen lamps, also referred to as tungsten-halogen lamps, are a type of incandescent lamp with two important improvements: the bulb is filled with gas and has an inner coating that reflects heat and improves the operating efficiency of the lamp. Halogen lamps are most commonly used for directional lighting, such as in track light and spot light luminaires, and in torchieres.

6.1.5 Light-emitting diode (LED)

LED lamps, also referred to as solid state lighting (SSL) lamps, are semiconductor devices that produce light when an electric current is passed through them, causing electrons to drop to lower energy orbits and release the excess energy as photons. LED lamps are relatively new technology and also are highly efficient and have much longer lifetimes than practically all other types of lamps.

6.1.6 High-intensity discharge

High-intensity discharge lamps are a type of discharge lamp that use an electric are to produce intense light. The three most common type of HID lamps are mercury vapor, metal halide, and high-pressure sodium. Due to the intensity of the light emitted, HID lamps are mostly used for exterior lighting.

6.2 Luminous Efficacy

The energy efficiency of a lamp is generally represented in terms of luminous efficacy, or efficacy for short. Luminous efficacy is a measure of how well a lamp converts electrical power to light and is typically represented in units of lumens per watt (lm/W). Efficacy varies by type of lamp, manufacturer, wattage, and age, among other factors. **Tables 29 and 30** demonstrate how efficacy varies as a function of wattage for CFL lamps and incandescent lamps, respectively.

In the absence of detailed data on the types and performance of the lamps used in the residential sector of the UAE, average or typical values reported in the literature were reviewed. **Table 31** shows the average efficacies used in the EU study discussed previously. Data are provided for the specific types of lamps used to model the residential sector and estimate the impacts of a lighting standard. **Table 32** shows the data reported in the U.S. DOE study, which includes efficacy values for additional lamp technologies and for a much wider variety of lamp types. In addition, this study provides overall or weighted averages for residential lighting, regardless of wattage and other factors.

Table 29. Initial Luminous Efficacy of CFL Lamps (IFC, 2006)

Wattage	Initial Luminous Efficacy, lm/W	
	6500K to 5000K CCT[a]	4000K to 2700K CCT[a]
≥ 5 < 9	46	50
≥ 9 to < 15	52	55
≥ 15 to < 25	57	60
≥ 25 to ≤ 60	62	65

[a] Correlated color temperature.

Table 30. Luminous Efficacy of Incandescent Lamps (IFC, 2006)

Wattage	Lumens	Efficacy, lumens/watt
25	≥ 230	≥ 9.2
40	≥ 415	≥ 10.4
50	≥ 570	≥ 11.4
60	≥ 715	≥ 11.9
75	≥ 940	≥ 12.5
90	≥ 1,227	≥ 13.6
100	≥ 1,350	≥ 13.5
150	≥ 2,180	≥ 14.5
200	≥ 3,090	≥ 15.5

Table 31. Average Luminous Efficacy Used for EU Study (VITO, 2009)

Lamp Technology	Lamp Type	Wattage	Efficacy, lm/W
Incandescent	Clear, form A,E27/B22dGLS-C	200	15.2
	Frosted, form A, E27/B22dGLS-F	60	11.4
	Clear, form A, E27/B22dGLS-C	60	11.8
	Frosted, form B, E14/B15dGLS-F	40	9.9
	Clear, form B, E14/B15dGLS-C	40	10.4
Compact fluorescent (CFL)	Bare, E27/B22dCFLi	15	50
	Enveloped form A, E27/B22dCFLi	15	45
	Bare, E14/B15dCFLi	10	50
	Enveloped form B, E14/B15dCFLi	10	40
Halogen	Clear, 230 V, G9, HL-MV	40	12.3
	Clear, 230 V, linear, R7s, HL-MV	300	17.7
	Clear, 12 V,GY6, 35, HL-LV	50	17.1
	Clear, 12 V,GY6, 35, HL-LV	35	15.4

Table 32. Average Luminous Efficacy Used for U.S. DOE Study (U.S. DOE, 2012a)

Lamp Technology	Type/Design	Average Efficacy, lumens/watt
Incandescent	**Overall average**	12.1
	General Service - A-type	12.9
	General Service - Decorative	10.9
	Reflector	10.2
	Miscellaneous	11.9
Compact fluorescent (CFL)	**Overall average**	52.1
	General Service - Screw	53.0
	General Service - Pin	59.1
	Reflector	43.1
	Miscellaneous	52.1
Linear fluorescent	**Overall average**	67.3
	T5	53.3
	T8 Less than 4ft	55.4
	T8 4ft	72.9
	T8 Greater than 4ft	87.0
	T12 Less than 4ft	51.8
	T12 4ft	66.7
	T12 Greater than 4ft	74.5
	T8 U-Shaped	77.3
	T12 U-Shaped	63.3
	Miscellaneous	62.7
Halogen	**Overall average**	14.3
	General Service	15.0
	Reflector	14.1
	Low Voltage Display	16.8
	Miscellaneous	13.8
Light emitting diode (LED)	**Overall average**	40.7
High intensity discharge	**Overall average**	62.4
	Mercury Vapor	29.3
	Metal Halide	49.0
	High Pressure Sodium	70.1
	Low Pressure Sodium	N/A

6.3 Estimated Distribution of Lamp Technologies in the UAE

The following paragraphs describe the various sources of data on lamp technologies available for the analysis: the voluntary residential lighting survey, the limited market survey, data request to the Middle East Lighting Association, and the building survey to be conducted by Abu Dhabi in support of the comprehensive cooling plan for the Emirate.

6.3.1 Voluntary Residential Lighting Survey

To supplement the data collected from other sources, a voluntary lighting survey was developed for collecting information on residential lighting. The survey requested information on the type and location of the respondent's residence; the types, numbers, relative intensity, and wattage of lamps in various rooms within the residence; and, for any respondent who lived in a villa, similar information on exterior lighting. Appendix IV includes the final draft of the survey questionnaire.

The survey was implemented on line through the Survey Monkey website in April, 2012. Prior to launching the survey, it was pre-tested and customized to meet the requirements and specifications of Survey Monkey. In addition, to ease the burden on the respondents, they were instructed to provide data on only three rooms. Thirty volunteers were recruited from the EWS volunteer list and each was asked to contact 10 other persons to complete the survey. In addition, staff members of RTI Office in Abu Dhabi were asked to complete the survey.

A total of 204 responses were received, although several of the responses were incomplete. Thirty nine responses were from persons living in villas, 164 from apartment dwellers, and, for one respondent, the residence was indicated as a studio. **Table 33** shows a breakdown by housing unit type.

Table 33. Breakdown of Voluntary Survey Responses by Housing Unit Type

Housing Unit Type	No. of Responses	% of Total
Flat/Apartment	164	80.4%
Other (Studio)	1	0.5%
Villa	39	19.1%
Total	204	100.0%

All seven of the Emirates were represented by the data, although more than half of the respondents live in Dubai (56.4%). Several responses were from residents of Abu Dhabi (26.5%) and Sharjah (14.2%). The remaining responses were from the other four Emirates: three responses from Ajman, and one each from Fujairah, Ras Al Khaimah, and Umm Al Quwain. **Table 34** shows the distribution of responses by Emirate, and **Figure 5** shows the results graphically.

Table 34. Breakdown of Voluntary Survey Responses by Housing Unit Type

Emirate	No. of Responses	% of Total
Abu Dhabi	54	26.5%
Ajman	3	1.5%
Dubai	115	56.4%
Fujairah	1	0.5%
Ras Al Khaimah	1	0.5%
Sharjah	29	14.2%
Umm al Quwain	1	0.5%
Total	204	100.0%

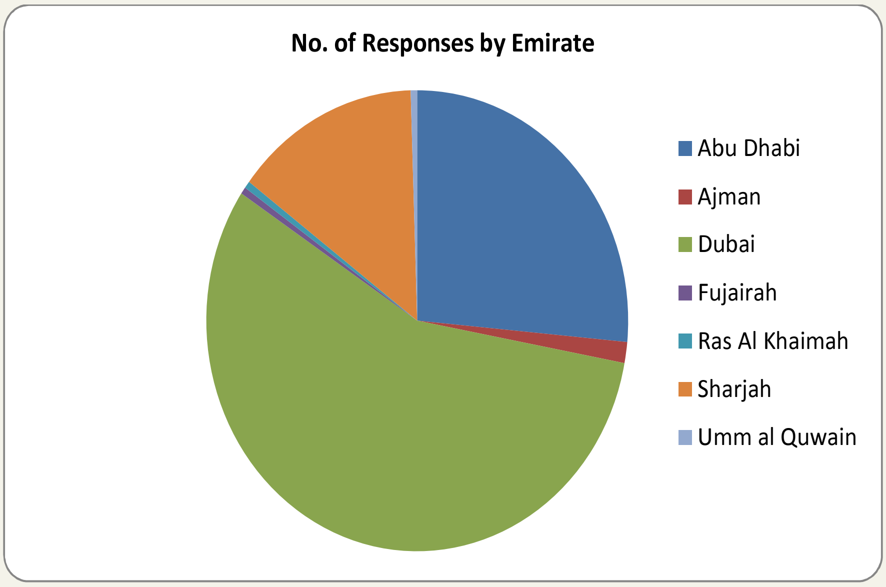

Figure 5. Breakdown of Survey Responses by Emirate

The detailed data on lamp types, numbers, and wattage were compiled into a format more suitable for analysis, and then reviewed for quality and consistency. Appendix V shows the formatted data, as received. Although it was concluded that the data could not be used to fully characterize lamp technology, rating, and usage by type of room, the data appear to provide a good representation of the types and distribution of lamps used in the residential sector. **Tables 35 and 36** show the distribution of lamps by technology for villas, apartments, and overall, regardless of residence type. Table 35 summarizes all of the data, as received, and Table 36 shows a summary of only the responses that appeared to be complete and unambiguous.

One of the more surprising results is the high percentage of linear fluorescent lamps reported for villas: linear fluorescent lamps accounted for 36.8% of villa lamps based on all of the responses and 48.3% of villa lamps based on only the complete responses. One possible explanation is that many villa residents selected kitchens as one of the three rooms covered by their responses, and it appears that kitchens are much more likely to have linear fluorescent lamps than any other type of room. A number of responses also reported luminaires with 12 to 20 linear fluorescent lamps, which seems unusually high and could be the result of incorrect lamp identification or incorrect data entry.

Table 35. Distribution of Lamp Technology by Housing Unit Type – All Data

Lamp Technology	Flat/Apartment		Villa		Total	
	No. of Lamps	% of Total	No. of Lamps	% of Total	No. of Lamps	% of Total
Incandescent	564	37.6%	103	24.9%	667	34.8%
Compact fluorescent (CFL)	490	32.6%	110	26.6%	600	31.3%
Linear fluorescent	293	19.5%	152	36.8%	445	23.2%
Halogen	100	6.7%	12	2.9%	112	5.9%
Light-emitting diode (LED)	54	3.6%	36	8.7%	90	4.7%
Total	1501	100.0%	413	100.0%	1914	100.0%

Table 36. Distribution of Lamp Technology by Housing Unit Type – Complete Responses Only

Lamp Technology	Flat/Apartment		Villa		Total	
	No. of Lamps	% of Total	No. of Lamps	% of Total	No. of Lamps	% of Total
Incandescent	261	37.7%	29	16.9%	290	33.6%
Compact fluorescent (CFL)	213	30.8%	50	29.1%	263	30.4%
Linear fluorescent	151	21.8%	83	48.3%	234	27.1%
Halogen	40	5.8%	6	3.5%	46	5.3%
Light-emitting diode (LED)	27	3.9%	4	2.3%	31	3.6%
Total	692	100.0%	172	100.0%	864	100.0%

6.3.2 Limited Market Survey

During the weeks of 5 and 12 February, 2012, staff members of the RTI Office in Abu Dhabi surveyed six establishments in Abu Dhabi that sell lighting products. Data were collected on lamp manufacturer, technology, wattage, and price for all lamps on display. **Table 37** summarizes the results of the survey. The detailed results of the market survey are provided in Appendix VI.

Although the data cannot be used to estimate the actual distribution of lamp technologies in the residential sector, the data do show the types of lamp technologies available. In addition, the relative number of products on the shelves provides some indication of how much each technology is used. For example, the large selection of CFL and incandescent lamps on display at the six stores visited is an indicator that these lamp types are frequently purchased and used.

It should also be noted that, other than for linear fluorescent lamps, the market survey data are consistent with the results of the voluntary lighting survey with respect to the types and relative numbers of lamp technologies used in the residential sector. Both surveys show relatively heavy use of incandescent and CFL lamps and limited use of halogen and LED lamps.

Table 37. Results of Limited Lighting Market Survey

Lamp Technology	Wattage	No. of Products	Average Price, AED
Incandescent	< 40 W	1	1.75
	40 W	7	2.67
	60 W	8	1.36
	75 W	2	2.63
	100 W	7	2.01
	>100 W	3	5.33
Compact fluorescent (CFL)	< 10 W	10	9.85
	11 to 14 W	6	12.23
	15 to 19 W	6	13.08
	20 to 23 W	18	15.20
	24 to 26 W	5	5.00
Linear fluorescent	18 W	2	3.20
	36 W	1	5.00
Halogen	< 30 w	4	10.50
	50 W	5	4.33
Light-emitting diode (LED)	1 to 3 W	3	37.30
	4 to 10 W	3	115.00
	15 to 30 W	3	102.00

6.3.3 Middle East Lighting Association (MELA) Data

MELA provided aggregated data on total lamp sales by MELA member companies for the years 2010 and 2011 for the following lighting technology categories: incandescent, CFL, halogen, and LED (MELA, 2012a; MELA, 2012b). Due to the confidentiality of the data, specific details cannot be provided in this report. However, the data were used to develop the recommended baseline distribution of lamps, as described further in Section 6.3.5 and summarized in **Table 38**.

6.3.4 Abu Dhabi Comprehensive Cooling Plan Building Survey

For the past year, the government of Abu Dhabi has been developing a Comprehensive Cooling Plan (CCP) with the primary objective of identifying, prioritizing, and implementing specific measures to reduce electricity consumption for residential, commercial, and institutional air conditioning in the Emirate. To support and refine the findings of the research conducted to date, Abu Dhabi will be conducting a survey of 1,500 buildings to collect data on building design, construction, and usage, and cooling system design, operation, and condition. Because lighting can significantly impact cooling load, the survey also will collect data on lighting technologies and usage. It is expected that the lighting data collected through the CCP building survey will greatly help in characterizing residential lighting for the Abu Dhabi Emirate and the UAE in general.

6.3.5 Recommended Distribution of Lamp Technologies for Baseline Assessment

A comparison of the data from the voluntary survey and the data provided by MELA shows significant differences in the relative distribution of incandescent and CFL technologies. The voluntary survey indicates much higher use of CFL lamps and much lower use of incandescent lamps. The voluntary survey also shows extensive use of linear fluorescent lamps, which are not included in the data from MELA. If we assume that the participants of the voluntary survey are more energy-conscious than most people, there is reason to think that the voluntary survey results are biased in favor of more efficient lighting. On the other hand, there is no reason to suspect that the MELA data are biased toward less efficient lighting. Therefore, the MELA data were used as the primary basis for the lamp technology distribution with one exception, the prevalence of linear fluorescent lighting. As noted previously, the voluntary survey indicated a relatively high percentage of linear fluorescent lighting. Information provided from the Ministry of Public Works indicated on specifications for villas used for National housing also indicated relatively high use of built-in linear fluorescent luminaires (MOPW, 2006). To account for this, it was assumed that 20% of all residential lighting was provided by linear fluorescent lamps, and the relative percentage of the other lamp technologies, as indicated by the data from MELA, was adjusted accordingly. Table 38 shows the resulting recommended distribution of lamp technologies for the baseline survey. Although it is recognized that the distribution of lamp technologies actually in use in the residential sector is likely to differ by typology (e.g., villas vs. apartments), there simply are not adequate data to draw such distinctions

Table 38. Recommended Distribution of Lamp Technologies for Baseline Assessment

Lamp Technology	Percentage of total
Incandescent	50.1%
Compact fluorescent (CFL)	21.8%
Linear fluorescent	20.0%
Halogen	7.8%
Light-emitting diode (LED)	0.2%
Total	100%

For comparison purposes, the distribution of lamp technologies in the EU and U.S. are summarized in **Table 39**. The EU data are from 2007, and show a lower percentage of CFL lamp use. However, it is likely the prevalence of CLF in the EU is much higher now and may be comparable to, or higher than the percentage of CFL lamps indicated in Table 38. The percentage of CFL lamps in the U.S. is comparable to the estimated percentage for the UAE, but also is likely to have increased in the 2 years since the data were compiled. The largest difference in the distribution is for linear fluorescent lamps, which are significantly less prevalent in the EU and U.S., and halogen lamps, which were in much wider use in the EU when the data were collected.

Table 39. Distribution of Lamp Technologies in Residential Units in the EU and US

Lamp Technology	European Union (2007)[a]	United States (2010)[b]
Incandescent	54.0%	62.0%
Compact fluorescent	14.7%	22.8%
Linear fluorescent	7.5%	9.9%
Halogen	23.7%	4.4%
Other	Not reported	0.9%[c]
Total	100.0%	100.0%

[a] VITO, 2009.
[b] U.S. DOE, 2012a.
[c] Includes LED, HID, and other lamp technologies.

It should be noted that the recommended distribution of lamp technologies that is presented in Table 38 does not include HID lamps. There are several reasons for this exclusion. HID lamps are generally used for exterior lighting and, because of their intensity, are placed at relatively high locations, making them difficult to identify and categorize. For this reason, they were excluded from the voluntary lighting survey. Based on data from the U.S., HID lamps represent a small percentage of lighting in the residential sector: only 0.025% of residential lamps are HID, HID lamps account for only 0.3% of annual lumen-hours, and in terms of annual electricity consumption, HIDs account for only 0.11% of lighting electricity consumption in the U.S. residential sector (U.S. DOE, 2012a). Finally, HID lamps are generally high efficiency, and most are comparable to CFL and LED lamps in terms of efficacy. Therefore, there would be no significant benefit in terms of efficiency gains by replacing HID lamps with other lamp technologies.

6.4 Estimated Number of Lamps by Residential Typology

Determining the number of each type of lamp for each residential typology requires applying the illuminance requirements summarized in Table 24 to the lamp technology distribution summarized in Table 38. Since the illuminance requirements are specified by room type, lamp distribution was also determined by room type. The following paragraphs describe the methodology used.

6.4.1 Distribution of Lamps by Technology and Room Type

As a starting point, the data from the voluntary lighting survey were reviewed. Data from only those survey responses that were complete and internally consistent were compiled by room and lamp type (e.g., number of incandescent lamps located in bedrooms). **Table 40** summarizes the resulting distribution.

Table 40. Voluntary Survey Summary of Lamps by Technology and Room Type

Room Type	Incandescent	CFL	Linear Fluorescent	Halogen	LED	Total
Washroom	14	6	20	3	9	51
Bedroom	110	104	36	11	10	270
Dining room	19	10	12	4	0	45
Hallway	11	9	15	14	0	49
Kitchen	24	33	119	9	7	192
Living room	141	130	32	5	5	313
Total	318	291	234	46	31	920
% of total lighting	34.6%	31.6%	25.4%	5.0%	3.4%	100%

Next, it was assumed that each lamp was comparable in terms of lumens produced, and the percentage of total lighting provided by each technology was determined. These percentages are shown as the bottom row in Table 40. At that point, the number of each lamp type was adjusted first to expand the room types to include all room types for the final typologies. For example, foyers and utility rooms, which were not included in the voluntary survey data, were added. The number of lamps was adjusted again across room types using a trial and error method until the target distribution (as shown in Table 38) was achieved, while maintaining the same total number of lamps. **Table 41** shows the results of this exercise.

Table 41. Final Distribution of Lamps by Technology and Room Type

Room Type	Incandescent	CFL	Linear Fluorescent	Halogen	LED	Total
Foyer	4	2				6
Corridor	13	4		30		47
Kitchen	50	24	105	24	1	204
Dining room	26	12				38
Living room	94	40	27	18		179
Family room	80	39				119
Washroom	26	10	20			56
Bedroom	160	68	32		1	261
Utility room	2					2
Garage	3	1				4
Exterior	3	1				4
Total	461	201	184	72	2	920
% of total lighting	50.1%	21.8%	20.0%	7.8%	0.2%	

6.4.2 Selection of Lamps to Represent Baseline

The next step was to select specific lamps, by technology and rating, to represent the baseline. The selections were based on the types of lamps typically found in the residential sector and on the available data (voluntary survey, limited market survey, and MELA data). To represent incandescent lighting, three lamps were selected: 40W, 60W and 100W. To determine comparable CFL lighting, the data on luminous efficacy shown in Tables 29 and 30 were used to select three types of CFL lamps to represent the residential sector: 8W, 14W, and 23W CLFs. (See the following paragraphs for further discussion of CFLs.) A single 18W linear fluorescent lamp was selected to represent linear fluorescent lighting. For halogen lighting, two lamps were selected: 20W and 50W. Finally, for LED lighting, two lamps were selected: 6W and 25W.

Since CFLs are expected to play a critical role in the implementation of a lighting standard, the quality of CFL lamps is an important consideration. A search for information on the quality of CFLs in international markets yielded a single study, which was published in 2007 by the U.S. Agency for International Development and focused on CFLs found in Asian markets (USAID, 2007). The report, which provided data for six Asian countries, estimated that the market share for poor quality CFLs ranged from 15% in Thailand to 55% in China. The report categorized poor quality CFLs as any that "… burns out faster, or gives off less light, than advertised, or than prescribed by national standards and guidelines." Although the report does not provide technical performance data on poor quality CFLs, it categorizes poor quality CFLs as those having a luminous efficacy less than 45 lm/W and an average lifetime of less than 6,000 hours.

Based on the threshold value of 45 lm/W presented in the USAID report, it was assumed that the average efficacy for poor quality CFLs is 35 lm/W. When compared to the 52 lm/W average luminous efficacy of residential CFL lamps (U.S. DOE, 2012a), this value equals about 67% of the efficacy of a good quality CFL. Three poor quality CFLs were selected (14W, 23W, and 28W) as providing comparable lighting to the 8W, 14W, and 23W good quality CFLs discussed above. **Table 42** summarizes the final lamp selections.

The final data point needed to determine the lamp distribution was the relative percentage of poor quality CFL lamps. Based on the available data, it was assumed that poor quality CFLs comprise 15% of the CFL lamps used in the UAE's residential sector.

Table 42. Lamps Used to Represent Baseline

Lamp Technology	Rating
Incandescent	40W, 60W, 100W
CFL, good quality	8W, 14W, 23W
CFL, poor quality	14W, 23W, 28W
Linear fluorescent	18W
Halogen	20W, 50W
LED	6W, 25W

6.4.3 Final Lamp Distribution by Residential Typology

Using the distribution listed in Table 41, the relative percentage of lighting was determined by room type and lamp technology. These percentages were applied to the lamps listed in Table 42, after making some basic assumptions about their relative distribution within a room (e.g., it was assumed that all foyer lamps would be relatively dim, such as 40W incandescent or 8W CFL lamps). **Table 43** shows the percentage of lamps by room and type. Based on the lighting requirements for each room type, which were determined using the illuminance criteria shown in Table 24 and the floor space data in Tables 14 to 19, the number of lamps per room were estimated by typology. After rounding up to whole numbers, the final lamp distributions were determined. **Table 44** summarizes the distribution of lamps by typology used for the baseline assessment. **Table 45** summarizes the total estimated number of lamps used in the residential sector of the UAE for the baseline year of 2011.

Table 43. Percentage of Lamps by Technology and Room Type

Room	Incandescent			CFL, High Efficiency			CFL, Low Efficiency			LFL	Halogen		LED	
	40	60	100	8	14	23	14	23	28	18	20	50	6	25
Foyer	66.7%			28.3%			5.0%							
Corridor	6.9%	20.7%		1.8%	5.4%		0.3%	1.0%			21.3%	42.6%		
Kitchen		6.1%	18.4%		2.5%	7.5%		0.4%	1.3%	51.5%	2.9%	8.8%		0.5%
Dining room	34.2%	34.2%			26.8%			4.7%						
Living room		52.5%			19.0%			3.4%		15.1%	2.5%	7.5%		
Family room		67.2%			27.9%			4.9%						
Washroom		31.0%	15.5%		10.1%	5.1%		1.8%	0.9%	35.7%				0.0%
Bedroom		61.3%			22.1%			3.9%		12.3%			0.2%	0.2%
Utility room			100%			0.0%			0.0%					
Garage			75.0%			21.3%			3.8%					
Exterior		75.0%			21.3%			3.8%						

Table 44. Distribution of Lamps by Residential Typology

Room	Number of Lamps by Room and Typology													
	Studio Apt	1-BR Apt.	2-BR Apt.	3-BR Apt.	4+BR Apt.	Small villa	Medium villa	Large villa	Part of Villa	One Story Building	Public House	Part of Public House	Separate Rooms	Arabic House	Others
Foyer	1	2	2	2	2	3	6	12	1	2	3	1	2	3	5
Corridor		2	3	4	6	5	13	32	1	4	5	1		5	8
Kitchen	3	5	5	5	6	6	15	29	2	5	6	2		6	17
Dining room	3	5	5	5	6	7	18	38	2	5	7	2		7	19
Living room		6	5	6	7	5	15	38	1	6	5	1		5	21
Family room						8	22	57	2		8	2		8	
Washroom	3	3	5	5	8	12	41	130	3	5	12	3		12	9
Bedroom	3	4	7	11	15	9	27	80	2	11	9	2		9	15
Utility room			1	1	1	1	2	5	1	1	1	1		1	
Garage						4	8	16	1		4	1		4	
Exterior			2	2	2	4	6	8	4	2	4	4		4	
Total	13	27	35	41	53	64	173	445	20	41	64	20	2	64	94

Table 45. Estimated Number of Residential Lamps by Emirate

Emirate	No. of Lamps
Abu Dhabi	30,088,887
Ajman	21,121,452
Dubai	12,508,381
Fujairah	3,420,584
Ras Al Khaimah	1,769,724
Sharjah	11,176,973
Umm al Quwain	4,940,484
Total	85,026,485

7. Baseline Estimate of Electricity Consumption

This section presents the results of the baseline assessment. Section 7.1 presents a summary of all the assumptions used in the analysis. The remainder of this section presents the results of the analysis and discusses the results and next steps.

7.1 Summary of Assumptions

This section provides a summary of the assumptions used for the baseline assessment. Where applicable, the corresponding table showing the intermediate basis or final values for the assumptions is indicated in parentheses.

- The baseline year for the analysis is 2011.
- Estimates of number of housing units for all Emirates except Dubai are based on 2005 NBS data (Table 5).
- For Dubai Emirate, the number of housing units is based on data obtained from the DSC website (Table 6).
- Population growth rates were determined based on historical data (Table 2).
- The population growth rates were applied to the estimated number of housing units to provide an estimate of the number of housing units in 2011 (Table 13).
- Fifteen residential housing unit typologies were defined (Table 7).
- Three villa typologies were defined based on data from Abu Dhabi (Table 8).
- Five apartment typology floor space values were defined based on data from Abu Dhabi (Table 11).
- The distribution of apartment typologies is based on data from DSC (Table 10).
- The remaining seven typologies represent all other housing unit categories listed in NBS data (Table 5).
- Estimated floor space for the Part of Villa typology is based on villa data from Abu Dhabi, using data for all buildings with less than 100 m^2 of floor space.
- To estimate the floor space for the typologies other than apartments and villas, each typology was matched to either a villa or apartment typology (Table 12).
- Villa typology layouts were developed by applying floor space data to floor plans obtained from websites (Table 19).
- Apartment typology layouts were developed using floor space data (Table 11) and informed assumptions about relative room sizes and numbers (Tables 14 through 18).
- Illuminance criteria are based on illuminance targets presented in *The Lighting Handbook* (IES, 2011) (Table 22).
- Since illuminance criteria represent minimum levels of lighting, values were increased by 25% to provide an estimate of actual lighting levels.
- To account for luminaire losses, a typical factor of 30% was used based on *Light's Labour Lost, Policies for Efficient Lighting* (IEA, 2006)
- Final illuminance values used for the assessment included the 25% factor and luminance loss factor (Table 24).
- Lighting usage rates are based on a study by the U.S. DOE (Table 28).
- Luminous efficacy values for CFL and incandescent lamps are based on IFC data (Tables 29 and 30).

- Luminous efficacy values for halogen and LED lamps are based on U.S. DOE data (average values presented in Table 32).[2]
- Lamp technology distribution is based on the results of the voluntary residential lighting survey and data provided by MELA (Table 38).
- The percentage of lamp types by technology and room types are based on data from the voluntary lighting survey, adjusted to account for the lamp technology distribution (Table 43).
- The total number of lamps by room type and residential housing typology are based on the lighting requirements for each room type, illuminance criteria, and the floor space data (Table 44).

7.2 Results

Tables 46 to 53 show the results of the baseline assessment. Tables 46 to 52 show separate results for each Emirate. Included in these tables are the number of housing units by typology, annual lighting requirements in lumen hours per year (lm-hr/yr), and the estimated electricity consumption in gigawatt hours per year (GWh/yr) by typology for each lamp technology and totals for all typologies for the baseline year of 2011. Table 53 summarizes baseline electricity consumption by Emirate. Table 53 also shows the estimated population and number of housing units by Emirate for the baseline year of 2011.

[2] It should be noted that the luminous efficacy used for LED lamps (40.7 lumens/watt) is more representative of older LED technology than current LED lamps, which are comparable to CFLs lamps in terms of efficacy. For the baseline, it was assumed that the LEDs in use are likely to be older technology. However, for the purpose of estimating the technical and economic potential of replacing low efficiency lamps for energy efficient lighting, higher efficacy values are recommended for LED lamps (e.g., 52 to 56 lumens/watt).

Table 46. Baseline Annual Electricity Consumption for Residential Lighting: Abu Dhabi Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	62,777	6,356,909	16.58	1.93	2.41	0.80	0.03	21.75
1-Bedroom Apartment	106,524	13,055,126	57.70	6.63	7.20	7.21	0.07	78.82
2-Bedroom Apartment	121,711	17,721,027	93.21	9.55	9.34	9.52	0.09	121.72
3-Bedroom Apartment	15,227	21,458,063	13.43	1.38	1.28	1.45	0.01	17.56
4+-Bedroom Apartment	3,346	28,216,992	3.71	0.38	0.37	0.43	0.00	4.90
Small villa	18,331	34,576,088	28.14	2.89	2.07	2.01	0.02	35.13
Medium villa	26,439	97,051,420	105.12	11.02	8.82	7.63	0.07	132.65
Large villa	5,590	249,575,143	55.72	5.84	4.95	3.80	0.03	70.34
Part of Villa	11,257	8,564,436	6.31	0.58	0.35	0.29	0.00	7.53
One Story Building	52,389	21,458,063	46.22	4.76	4.39	4.98	0.05	60.40
Public House	69,038	34,576,088	105.98	10.88	7.80	7.56	0.06	132.30
Part of Public House	38,626	8,564,436	21.66	1.99	1.21	0.98	0.01	25.84
Separate Rooms	46,705	2,125,224	1.34	0.15	0.00	0.00	0.00	1.49
Arabic House	0	34,576,088	0.00	0.00	0.00	0.00	0.00	0.00
Others	57,904	52,220,502	109.67	12.67	13.22	14.39	0.13	150.09
Total	635,864	630,095,604	664.8	70.7	63.4	61.1	0.6	860.5
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 47. Baseline Annual Electricity Consumption for Residential Lighting: Dubai Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	60,897	6,356,909	16.09	1.87	2.34	0.78	0.03	21.10
1-Bedroom Apartment	103,335	13,055,126	55.98	6.43	6.98	7.00	0.07	76.46
2-Bedroom Apartment	118,067	17,721,027	90.42	9.27	9.06	9.24	0.09	118.08
3-Bedroom Apartment	14,771	21,458,063	13.03	1.34	1.24	1.40	0.01	17.03
4+-Bedroom Apartment	3,246	28,216,992	3.60	0.37	0.36	0.42	0.00	4.75
Small villa	25,345	34,576,088	38.91	4.00	2.86	2.78	0.02	48.57
Medium villa	36,555	97,051,420	145.34	15.24	12.20	10.55	0.09	183.41
Large villa	7,729	249,575,143	77.04	8.07	6.84	5.25	0.04	97.25
Part of Villa	959	8,564,436	0.54	0.05	0.03	0.02	0.00	0.64
One Story Building	0	21,458,063	0.00	0.00	0.00	0.00	0.00	0.00
Public House	2,850	34,576,088	4.38	0.45	0.32	0.31	0.00	5.46
Part of Public House	0	8,564,436	0.00	0.00	0.00	0.00	0.00	0.00
Separate Rooms	2,630	2,125,224	0.08	0.01	0.00	0.00	0.00	0.08
Arabic House	14,732	34,576,088	22.62	2.32	1.66	1.61	0.01	28.23
Others	1,006	52,220,502	1.91	0.22	0.23	0.25	0.00	2.61
Total	392,122	630,095,604	469.9	49.6	44.1	39.6	0.4	603.7
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 48. Baseline Annual Electricity Consumption for Residential Lighting: Sharjah Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	42,088	6,356,909	11.12	1.29	1.62	0.54	0.02	14.58
1-Bedroom Apartment	71,418	13,055,126	38.69	4.45	4.83	4.84	0.05	52.84
2-Bedroom Apartment	81,600	17,721,027	62.49	6.40	6.26	6.38	0.06	81.61
3-Bedroom Apartment	10,208	21,458,063	9.01	0.93	0.86	0.97	0.01	11.77
4+-Bedroom Apartment	2,243	28,216,992	2.48	0.26	0.25	0.29	0.00	3.28
Small villa	7,560	34,576,088	11.61	1.19	0.85	0.83	0.01	14.49
Medium villa	10,904	97,051,420	43.35	4.55	3.64	3.15	0.03	54.71
Large villa	2,305	249,575,143	22.98	2.41	2.04	1.57	0.01	29.00
Part of Villa	1,528	8,564,436	0.86	0.08	0.05	0.04	0.00	1.02
One Story Building	9,155	21,458,063	8.08	0.83	0.77	0.87	0.01	10.56
Public House	17,211	34,576,088	26.42	2.71	1.94	1.89	0.02	32.98
Part of Public House	2,299	8,564,436	1.29	0.12	0.07	0.06	0.00	1.54
Separate Rooms	19,632	2,125,224	0.56	0.06	0.00	0.00	0.00	0.62
Arabic House	19,436	34,576,088	29.84	3.06	2.20	2.13	0.02	37.24
Others	4,330	52,220,502	8.20	0.95	0.99	1.08	0.01	11.22
Total	301,917	630,095,604	277.0	29.3	26.4	24.6	0.2	357.5
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 49. Baseline Annual Electricity Consumption for Residential Lighting: Ajman Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	9,287	6,356,909	2.45	0.29	0.36	0.12	0.00	3.22
1-Bedroom Apartment	15,760	13,055,126	8.54	0.98	1.07	1.07	0.01	11.66
2-Bedroom Apartment	18,006	17,721,027	13.79	1.41	1.38	1.41	0.01	18.01
3-Bedroom Apartment	2,253	21,458,063	1.99	0.20	0.19	0.21	0.00	2.60
4+-Bedroom Apartment	495	28,216,992	0.55	0.06	0.05	0.06	0.00	0.72
Small villa	2,394	34,576,088	3.68	0.38	0.27	0.26	0.00	4.59
Medium villa	3,453	97,051,420	13.73	1.44	1.15	1.00	0.01	17.33
Large villa	730	249,575,143	7.28	0.76	0.65	0.50	0.00	9.19
Part of Villa	598	8,564,436	0.34	0.03	0.02	0.02	0.00	0.40
One Story Building	3,336	21,458,063	2.94	0.30	0.28	0.32	0.00	3.85
Public House	3,337	34,576,088	5.12	0.53	0.38	0.37	0.00	6.39
Part of Public House	771	8,564,436	0.43	0.04	0.02	0.02	0.00	0.52
Separate Rooms	4,356	2,125,224	0.12	0.01	0.00	0.00	0.00	0.14
Arabic House	8,275	34,576,088	12.70	1.30	0.94	0.91	0.01	15.86
Others	1,426	52,220,502	2.70	0.31	0.33	0.35	0.00	3.70
Total	74,477	630,095,604	76.4	8.1	7.1	6.6	0.1	98.2
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 50. Baseline Annual Electricity Consumption for Residential Lighting: Umm Al Quwain Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	896	6,356,909	0.24	0.03	0.03	0.01	0.00	0.31
1-Bedroom Apartment	1,520	13,055,126	0.82	0.09	0.10	0.10	0.00	1.12
2-Bedroom Apartment	1,737	17,721,027	1.33	0.14	0.13	0.14	0.00	1.74
3-Bedroom Apartment	217	21,458,063	0.19	0.02	0.02	0.02	0.00	0.25
4+-Bedroom Apartment	48	28,216,992	0.05	0.01	0.01	0.01	0.00	0.07
Small villa	962	34,576,088	1.48	0.15	0.11	0.11	0.00	1.84
Medium villa	1,388	97,051,420	5.52	0.58	0.46	0.40	0.00	6.96
Large villa	293	249,575,143	2.92	0.31	0.26	0.20	0.00	3.69
Part of Villa	42	8,564,436	0.02	0.00	0.00	0.00	0.00	0.03
One Story Building	2,467	21,458,063	2.18	0.22	0.21	0.23	0.00	2.84
Public House	4,944	34,576,088	7.59	0.78	0.56	0.54	0.00	9.47
Part of Public House	234	8,564,436	0.13	0.01	0.01	0.01	0.00	0.16
Separate Rooms	1,794	2,125,224	0.05	0.01	0.00	0.00	0.00	0.06
Arabic House	10,593	34,576,088	16.26	1.67	1.20	1.16	0.01	20.30
Others	1,150	52,220,502	2.18	0.25	0.26	0.29	0.00	2.98
Total	28,285	630,095,604	41.0	4.3	3.4	3.2	0.0	51.8
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 51. Baseline Annual Electricity Consumption for Residential Lighting: Ras Al Khaimah Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	4,757	6,356,909	1.26	0.15	0.18	0.06	0.00	1.65
1-Bedroom Apartment	8,072	13,055,126	4.37	0.50	0.55	0.55	0.01	5.97
2-Bedroom Apartment	9,223	17,721,027	7.06	0.72	0.71	0.72	0.01	9.22
3-Bedroom Apartment	1,154	21,458,063	1.02	0.10	0.10	0.11	0.00	1.33
4+-Bedroom Apartment	254	28,216,992	0.28	0.03	0.03	0.03	0.00	0.37
Small villa	8,037	34,576,088	12.34	1.27	0.91	0.88	0.01	15.40
Medium villa	11,591	97,051,420	46.08	4.83	3.87	3.34	0.03	58.16
Large villa	2,451	249,575,143	24.43	2.56	2.17	1.67	0.01	30.84
Part of Villa	1,305	8,564,436	0.73	0.07	0.04	0.03	0.00	0.87
One Story Building	18,093	21,458,063	15.96	1.64	1.52	1.72	0.02	20.86
Public House	27,939	34,576,088	42.89	4.40	3.16	3.06	0.03	53.54
Part of Public House	1,090	8,564,436	0.61	0.06	0.03	0.03	0.00	0.73
Separate Rooms	9,425	2,125,224	0.27	0.03	0.00	0.00	0.00	0.30
Arabic House	57,646	34,576,088	88.50	9.09	6.51	6.31	0.05	110.47
Others	6,567	52,220,502	12.44	1.44	1.50	1.63	0.02	17.02
Total	167,604	630,095,604	258.2	26.9	21.3	20.1	0.2	326.7
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 52. Baseline Annual Electricity Consumption for Residential Lighting: Fujairah Emirate

Typology	No. of Units	Annual Lighting Requirements per unit, lm-hr/yr	Annual Electricity Consumption, GWh/yr					Total, GWh/yr
Studio Apartment	5,393	6,356,909	1.42	0.17	0.21	0.07	0.00	1.87
1-Bedroom Apartment	9,152	13,055,126	4.96	0.57	0.62	0.62	0.01	6.77
2-Bedroom Apartment	10,457	17,721,027	8.01	0.82	0.80	0.82	0.01	10.46
3-Bedroom Apartment	1,308	21,458,063	1.15	0.12	0.11	0.12	0.00	1.51
4+-Bedroom Apartment	287	28,216,992	0.32	0.03	0.03	0.04	0.00	0.42
Small villa	2,927	34,576,088	4.49	0.46	0.33	0.32	0.00	5.61
Medium villa	4,222	97,051,420	16.79	1.76	1.41	1.22	0.01	21.18
Large villa	893	249,575,143	8.90	0.93	0.79	0.61	0.01	11.24
Part of Villa	327	8,564,436	0.18	0.02	0.01	0.01	0.00	0.22
One Story Building	13,060	21,458,063	11.52	1.19	1.09	1.24	0.01	15.06
Public House	21,287	34,576,088	32.68	3.36	2.41	2.33	0.02	40.79
Part of Public House	2,083	8,564,436	1.17	0.11	0.07	0.05	0.00	1.39
Separate Rooms	8,180	2,125,224	0.23	0.03	0.00	0.00	0.00	0.26
Arabic House	9,993	34,576,088	15.34	1.58	1.13	1.09	0.01	19.15
Others	2,887	52,220,502	5.47	0.63	0.66	0.72	0.01	7.48
Total	92,456	630,095,604	112.6	11.8	9.7	9.3	0.1	143.4
		Lamp technology	Incandescent	CFL	Lin. Fluor.	Halogen	LED	
		% of total	50.1%	21.8%	20.0%	7.8%	0.2%	

Table 53 summarizes the totals for residential lighting electricity consumption by Emirate. Total electricity consumption for residential lighting in 2011 is estimated to be 2,442 GWh, and ranges by Emirate from 52 GWh for Umm Al Quwain Emirate to 861 GWh for Abu Dhabi. For comparison purposes, the table also shows the estimated population and number of residential housing units for the baseline year of 2011.

Table 53. Summary of Baseline Electricity Consumption by Emirate

Emirate	2011 Population	No. of Housing Units	Lighting Electricity Consumption, GWh
Abu Dhabi	3,672,279	635,864	861
Dubai	1,567,552	392,122	604
Sharjah	1,433,480	301,919	357
Ajman	388,329	74,478	98
Umm Al Quwain	157,511	28,286	52
Ras Al Khaimah	884,280	167,605	327
Fujairah	594,997	92,456	143
Total	8,698,429	1,692,730	2,442

Figure 6 shows estimated consumption for lighting by typology. Medium size villas, 2-bedroom apartments, public houses, and large villas have the highest consumption. Total electricity consumption is a function of both the average consumption per residential unit and the total number of units. For example, even though large villas consume more than medium villas, there are five times as many medium villas as there are large villas; so the total consumption for medium villas is greater.

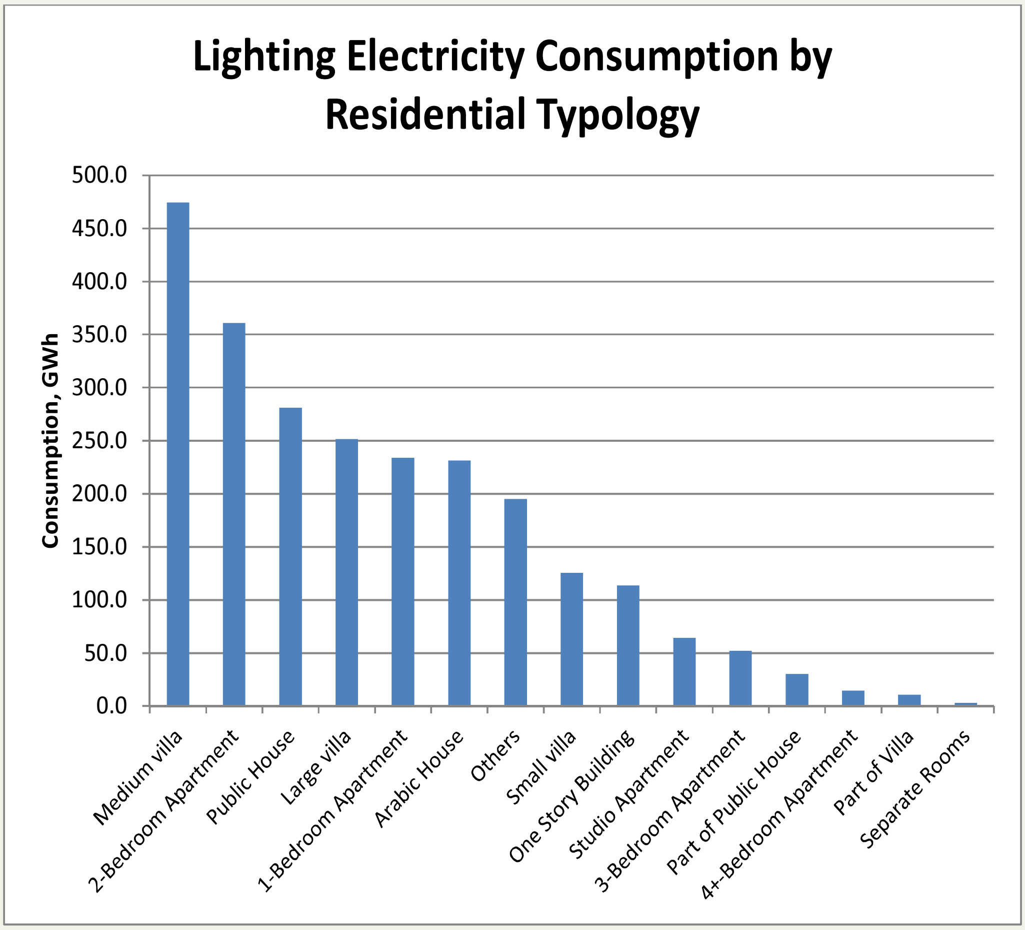

Figure 6. Lighting Electricity Consumption by Residential Typology

7.3 Discussion

To put these results into context, comparisons were made between the baseline estimate for residential lighting and other reported data on lighting consumption by the residential sector. The often-cited number for residential lighting as a percentage of total residential electricity consumption is 15%, which appears to be based on data published by the U.S. Department of Energy (U.S. DOE, 2010). However, the baseline estimate indicates a percentage of about 6%. In view of the extremely heavy cooling load in the UAE, it is reasonable to expect the percentage of consumption for residential lighting to be significantly less than in the U.S. This percentage is discussed further below. It should also be noted that this percentage includes indoor lighting for all apartments and exterior balcony lighting for apartments with two or more bedrooms. However, the baseline estimate does not include communal lighting for apartments, such as apartment building corridors, stairways, elevators, and lobbies. Since apartments account for about 30% of the baseline, and communal lighting should be no more than 10% of indoor lighting, including communal lighting would probably increase the lighting percentage of consumption by no more than a few tenths of a percent.

In response to the data request discussed in Section 1, Dubai Electricity and Water Authority (DEWA) provided information on total electricity consumption for the residential sector of Dubai in 2011 (9,307 GWh) and estimated residential lighting consumption for a typical villa (71,052 kWh) and typical flat (15,945 kWh) (DEWA, 2012). For all three metrics, DEWA estimated lighting to account for 15% of electricity consumption. Compared to the figure for total residential electricity consumption, the baseline estimate for Dubai (604 GWh) amounts to 6.5%. Comparing the reported consumption for a typical villa to a weighted average of the baseline estimates for villa typologies (4,728 kWh), indicates residential lighting accounts for about 6.7% of the total. A similar comparison of DEWA's estimate for a typical flat and a weighted average of the baseline estimates for the five apartment typologies (791 kWh) indicates lighting comprises about 5.0% of total electricity consumption.

Data obtained from the database used to develop the Comprehensive Cooling Plan for Abu Dhabi Emirate indicates residential electricity consumption in 2011 was 14,572 GWh (EAA, 2012). Comparing this figure to the baseline estimate for Abu Dhabi (861 GWh) indicates residential lighting amounts to 5.9% of total residential electricity consumption.

For the 2009 DSM Study for Abu Dhabi, lighting was estimated to be about 7% of total residential electricity consumption (EAA, 2009). However, the same study estimated cooling to account for 47% of the residential electricity use. Based on the analysis of cooling recently conducted in developing the comprehensive cooling plan for Abu Dhabi, it appears that cooling actually accounts for at least 60% of residential electricity use (EAA, 2012). If the cooling percentage is adjusted to a more representative value of 60%, lighting percentage decreases to about 5.3% of total residential electricity consumption.

Finally, a recent study on electricity load management and efficiency for the government of Saudi Arabia, indicated lighting accounted for about 5% of total electricity consumption by the residential sector (ECRA, 2011). If the estimated percentage for cooling (70%) in Saudi Arabia presented in the same study is adjusted to the estimated percentage for cooling in Abu Dhabi (60%), the percentage for lighting would be about 6.7%. Thus, the data from Saudi Arabia is in very good agreement with, and further supports, the results of the Baseline Assessment because it represents data from the same region with similar environmental conditions.

In summary, based on the assumptions described previously and the comparisons described above, the baseline estimates consistently show lighting to comprise about 6% of total electricity consumption for the residential sector of the UAE. There are several possible explanations for why this percentage might be so much less than the 15% value cited in the literature. The primary reason is that, due to the hot climate, cooling accounts for much greater share of electricity consumption in the UAE than in the US, Europe, and other regions. The more extensive use of CFL and linear fluorescent lamps in the UAE also act to reduce the percentage of consumption attributed to lighting. Latitude may also be a factor; European countries and the United States are located at higher latitudes where days are shorter and the need for lighting is greater.

7.4 *Sensitivity Analysis*

The sensitivity of the baseline consumption estimates to some of the primary assumptions used for the analysis by examining four scenarios: higher lighting usage rates, two different mixes of lamp technologies with lower and higher percentages of incandescent lamps, and a combination of higher usage rates and a higher percentage of incandescent lamps. **Table 54** summarizes the results of the analysis.

7.4.1 Scenario 1 – Increased Lighting Usage Rates

To see the effect of higher lighting usage rates on residential lighting consumption, an across-the-board usage assumption of 3.5 hr/day was applied to all lamps, as was used for the *Dubai CFL Project* (UNFCCC, 2011). Under this scenario, 2011 consumption would increase to 4,623 GWh and nearly double the baseline estimate of 2,442 GWh. In terms of percentage of total consumption, this would increase residential lighting to about 12% of total residential electricity consumption.

7.4.2 Scenario 2 – Increased Lighting Usage Rates Based on ESMA Survey

As described earlier, ESMA conducted an informal survey of 40 residences and obtained an estimated average of 7.5 hours per day. Although this survey did not account for partial lighting (i.e., the situation when some, but not all, lights are illuminated in a room), the energy consumption based on the usage rates by room type is presented in Table 54. Under this scenario, 2011 consumption would increase to 9,579 GWh. This is about four times the baseline estimate of 2,442 GWh. In terms of percentage of total consumption, this would increase residential lighting to about 25% of total residential electricity consumption.

7.4.3 Scenario 3 – 40% Incandescent Lamps

For this scenario, the percentage of incandescent lamps was decreased from the baseline level of 50% to 40%, with a corresponding increase in the percentages of CFL lamps from 22% to 32%. Under this scenario, 2011 consumption would decrease to 2,153 GWh, a decrease of 12% over baseline. In terms of percentage of total consumption, this would decrease residential lighting to 5.3% of total residential electricity consumption.

7.4.4 Scenario 4 – 60% Incandescent Lamps

For this scenario, the percentage of incandescent lamps was increased from the baseline level of 50% to 60%, with corresponding decreases in CFL lamps from 22% to 12%. Under this scenario, 2011 consumption would increase to 2,731 GWh, an increase of about 12% over baseline. In terms of percentage of total consumption, this would increase residential lighting to almost 7% of total residential electricity consumption.

7.4.5 Scenario 5 – Increased Lighting Usage and 60% Incandescent Lamps

This scenario is a combination of Scenarios 1 and 3: increased lighting usage to 3.5 hr/day for all lamps and increased percentage of incandescent lamps to 60%, with a corresponding decrease in CFL lamps to 12%. Under this scenario, 2011 residential lighting consumption would be 5,158 GWh, or about 2.1 times baseline. In terms of percentage of total consumption, this would correspond to residential lighting accounting for 12.6% of total residential electricity.

Table 54. Summary of Results for Alternate Scenarios

Scenario:	Baseline	1	2	3	4	5
Conditions:	Baseline	3.5 hr/day usage	ESMA daily usage estimate	40% Incandescent	60% Incandescent	3.5 hr/day usage, 60% incandescent
Emirate		Electricity Consumption, GWh				
Abu Dhabi	861	1,618	3,368	760	961	1,805
Dubai	604	1,151	2,361	532	675	1,285
Sharjah	357	675	1,399	315	400	753
Ajman	98	186	385	87	110	207
Umm Al Quwain	52	98	205	46	58	110
Ras Al Khaimah	327	622	1,294	287	366	694
Fujairah	143	272	567	126	161	304
Total	2,442	4,623	9,579	2,153	2,731	5,158

7.4.6 Impact of Growth Rates and Estimated Population on Baseline

The baseline electricity consumption and the estimated electricity consumption under the four scenarios discussed above all are a function of the population of the UAE. As discussed in Section 3, there is some uncertainty in population growth rates, and thus, there is uncertainty in the estimated population of each Emirate in the baseline year of 2011. Using the recommended growth rates presented in Section 3, the population of the UAE is estimated to be 8.7 million in 2011. However, depending on which population data are used to derive growth rates, the estimated population in 2011 could be as high as 16.4 million. This uncertainty has obvious impacts on the baseline. It is reasonable to assume that electricity consumption for residential lighting tracks the population growth such that, for example, if the population is underestimated by 20%, electricity consumption for residential lighting also is likely to be underestimated by 20%.

Since population growth typically is exponential, the uncertainty in population growth rates has an even greater impact on projected electricity consumption for residential lighting in future years.

7.5 Next Steps

This baseline assessment lays the groundwork for the estimate of technical potential and an analysis of the impacts of a residential lighting standard with respect to electricity consumption, the lighting market supply chain, air emissions, solid waste generation and disposal, and general sustainability.

The next step in the analysis is to determine the technical potential associated with a defined set of options for a lighting standard. For example, one option could be an efficacy standard that essentially eliminates the use of incandescent and halogen lamps. Based on the assumptions used in the analysis, the estimate that residential lighting accounts for 6% of total residential lighting is likely to be conservative. Thus, demonstrating that the technical potential is economically viable at the 6% level would further support the decision to proceed with a lighting standard.

7.6 Data Uncertainties and Improvements

As noted previously, there are several uncertainties in the data and assumptions used to estimate baseline consumption. Among the more significant uncertainties are the following:

- Current mix of lighting technologies in the residential sector
- Number of lamps typically used and usage rates for the various residential typologies

- Prevalence and performance of low quality CFL lamps in the market
- Population estimates and growth rates
- Number and lighting characteristics of the various types of residential housing units.

Although the data provided by MELA and collected through the voluntary survey have been helpful in characterizing the current mix of lighting technologies, more detailed data are needed. The CCP Building Survey can help to fill these data gaps, but completion of the survey is not expected until the Fall of 2012. The CCP Building Survey data can also help in better estimating the number of lamps and, possibly, lamp usage rates. Any additional data that can be provided by MELA will further help to reduce these uncertainties and refine the baseline assessment. Data on the prevalence and performance of low quality CFL lamps can best be obtained through product testing, and ESMA's planned testing program will be of great benefit in characterizing how significant an issue product quality is in the UAE. The uncertainties inherent in the available data on current population, population growth rates, and the number of residential housing units are significant, and efforts to collect additional data from NBS, DSC, and the Statistics Center of Abu Dhabi should be continued. As additional data become available, the data will be evaluated and used to fill data gaps, reduce uncertainties in, and refine the baseline assessment.

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Appendix I

Development of Representative Villas Based on Total Floor Space

Data Source

Data from the GIS Building and Plot Data Database (UPC, 2007), developed by the Abu Dhabi Urban Planning Council, was used as the basis for the analysis. The database includes data on building floor space, number of floors, geographic location, and other building features for more than 130,000 buildings in Abu Dhabi Emirate.

Development of Villa Data Set

Data on all buildings categorized as villas were extracted from the database.The resulting data set covered 51,241 buildings, which ranged in total floor space from 3.3 m^2 to 17,409 m^2.Recognizing that the buildings at the low end of the range were too small to comprise a villa, the decision was made to remove from the data set any building with less than 100 m^2 of total floor space.This action eliminated 9,229 buildings and resulted in a final data set of 42,012 buildings.As described in Section 4.2.3 of the report, the eliminated buildings were included in the baseline assessment to represent the Part of Villa and Part of Public House housing unit categories.

A summary of selected statistics for the final villa data set are provided below, and Figure I-1 shows a histogram of the data set grouped into bins of 500 villas.

Statistical Summary of Final Villa Data Set

Floor Space (m^2)					
Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
100.0	321.8	514.6	697.2	907.6	17,410.0

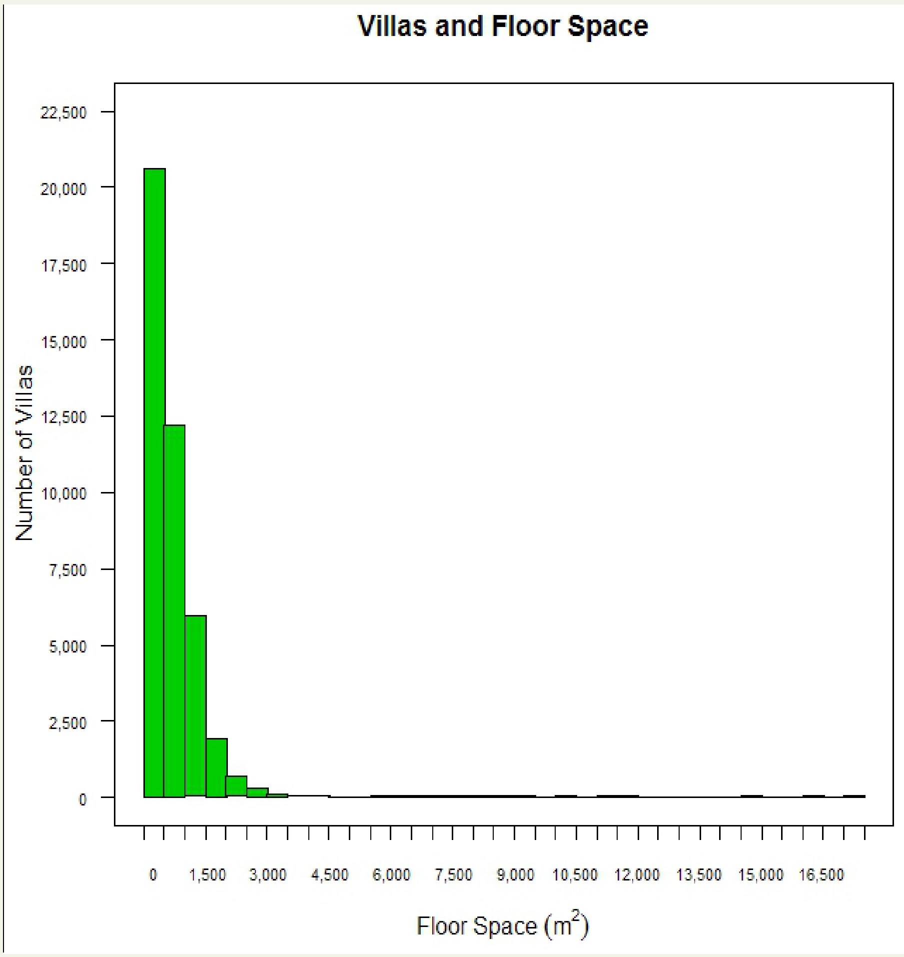


Figure I-1. Histogram of the villas with bins of 500 m^2.

Data Analysis

An exploratory data analysis was performed to determine boundaries for a class distribution based on floor space (m^2).The intent of the class distribution is to divide the data set into three size classes based on total floor space:small, medium, and large. Percentiles were used to determine the boundaries (cutoffs) for the three classes.The following table shows the percentiles of the floor space.

Villa Floor Space Percentiles

Percentiles	Floor Space (m^2)
0%	100.0
5%	157.3
10%	197.1
15%	223.4
20%	265.0
25%	321.8
30%	351.7
35%	398.0
40%	435.3
45%	452.2
50%	514.6
55%	602.3
60%	660.3
65%	703.6
70%	781.2
75%	907.6
80%	1,066.2
85%	1,211.6
90%	1,377.5
95%	1,726.6
100%	17,409.4

The cutoffs for the small, medium, and large brackets were calculated in two steps.First, two variables were calculated:*small* and *med*, as functions of the percentiles.

- small = (50% - 25%) / 2
- small = (514.6 - 321.8) / 2
- small = 96.4
- med = (80% - 50%) / 2
- med = (1,066.2 -514.6) / 2
- med = 275.8

Note that the 80th percentile was chosen instead of 75th percentiles because the 75th percentile was too close to the median floor space value.Next, the variables *small* and *med* were used to calculate the cutoffs for the different classes.

Calculation of Upper Limit for Small Class:

- cut1 = 25% + small
- cut1 = 321.8 + 96.45
- cut1 = 418

Calculation of Upper Limit for Medium Class:

- cut2 = 80% + med
- cut2 = 1,066.2 + 275.8
- cut2 = 1,342

This upper limit for the medium class (1,342 m^2) also defines the lower limit of the large class of villas.The tables below summarize the final size classes for villas. Figure I-2 is a histogram showing the villa size classes, and Figure I-3 shows box plots of the villa size classes.

Summary of Villa Classes and Floor Space

Villa Class	Floor Space Range (m^2)	Percent of Total	Number of Villas
Small	Floor Space ≤ 418	36.4%	15,292
Medium	418 < Floor Space ≤ 1,342	52.5%	22,068
Large	Floor Space > 1,342	11.1%	4,652
		Total	42,012

Statistical Summary of Small Villas

Small Villa Floor Space (m^2)					
Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
100.0	184.6	246.5	257.5	333.9	418.1

Statistical Summary of Medium Villas

Medium Villa Floor Space (m^2)					
Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
418.2	507.6	676.7	742.9	936.5	1,342.0

Statistical Summary of Large Villas

Large Villa Floor Space (m^2)					
Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
1,342	1,463	1,671	1,926	2,079	1,7410

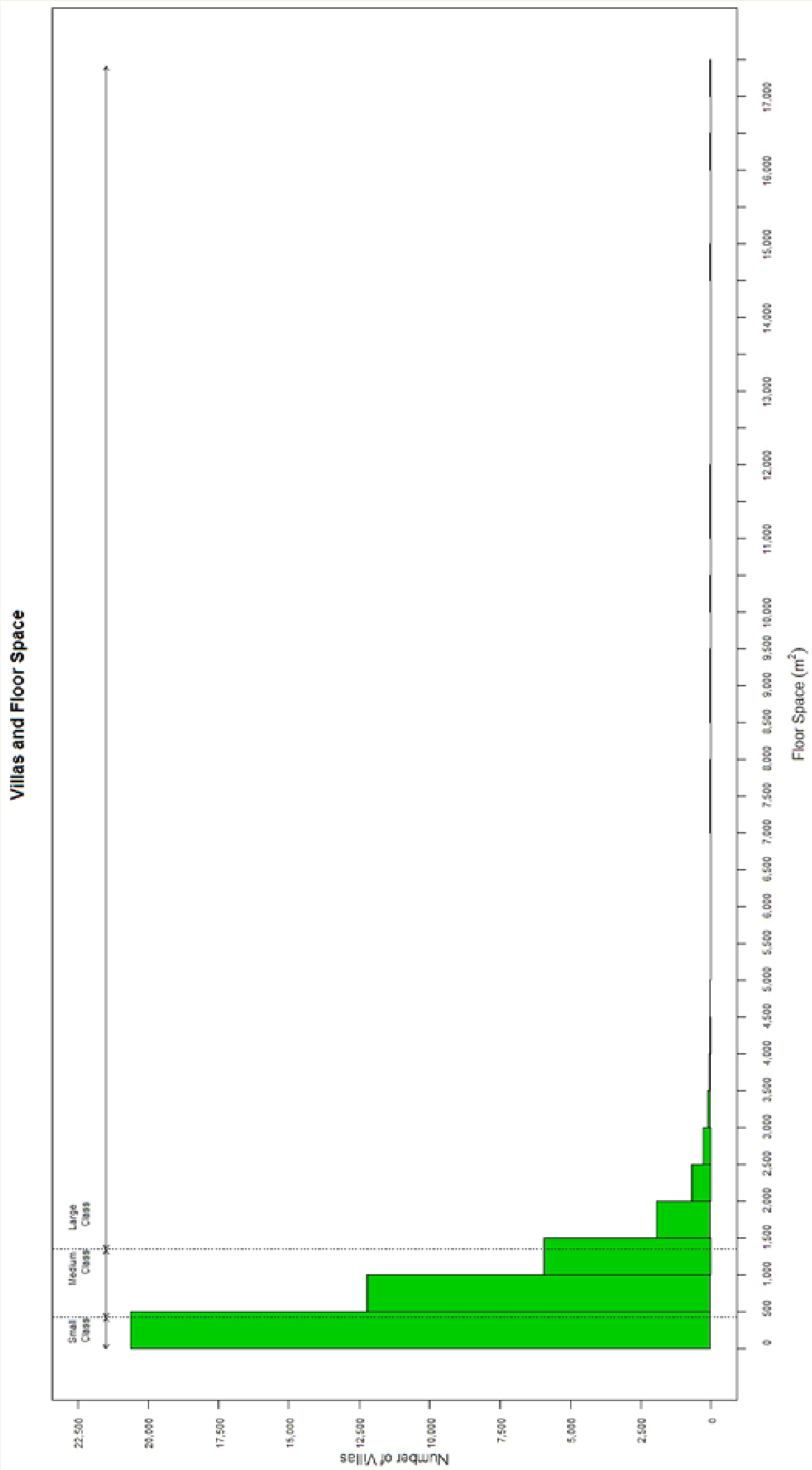


Figure I-2.Histogram of entire data with the villa classes identified.

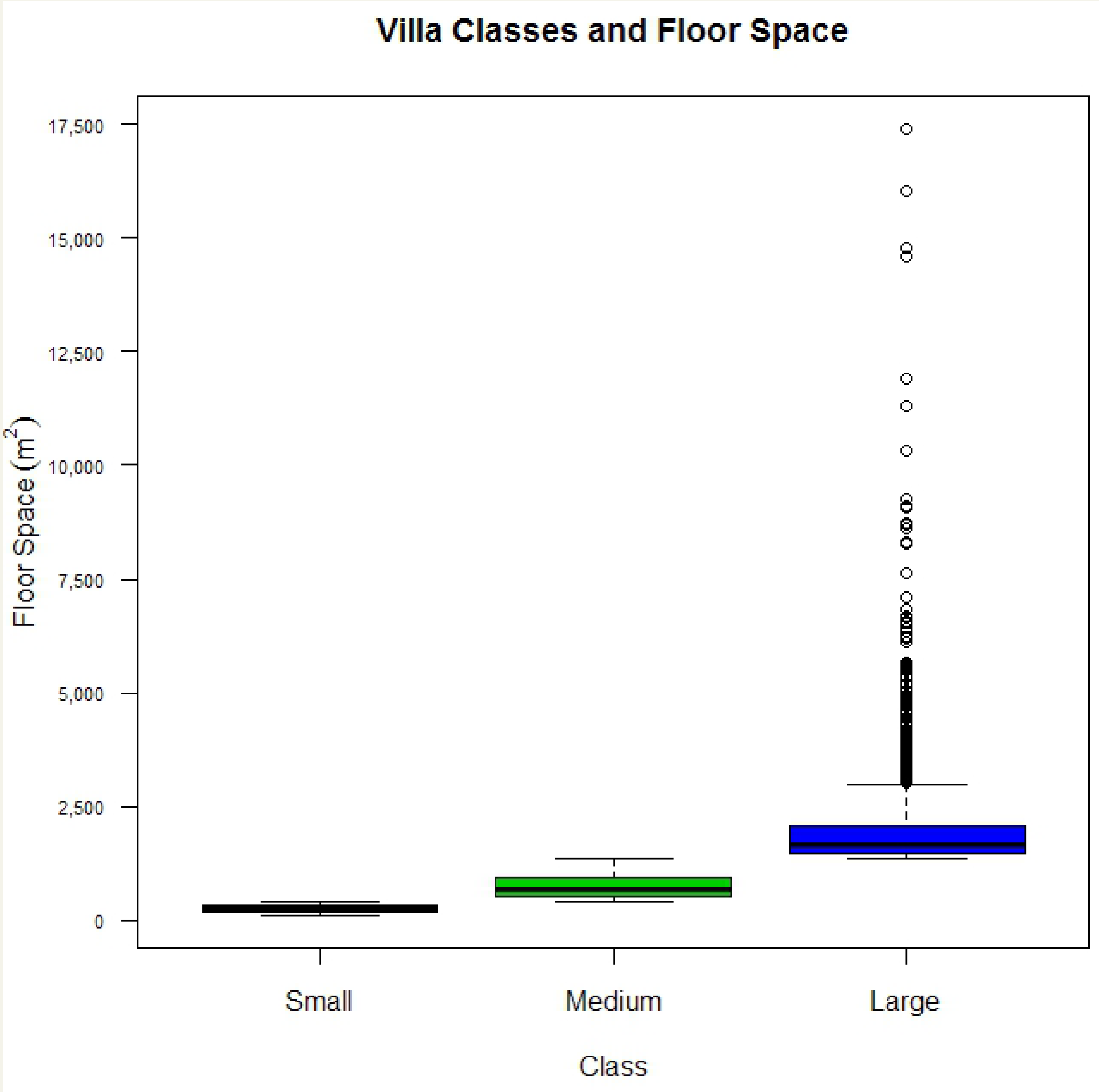


Figure I-3.Boxplot of each villa class and the floor space.

Appendix II

Summary of Lighting Codes and Standards for Dubai

Codes and Standards Reviewed

Code/Standard	Purpose
Dubai Municipality Department of Buildings and Housing: Building Code Regulations and Construction Specifications, February 2004	This document provides a list of building code regulations and construction specifications for the municipality of Dubai.
Green Building Regulations and Specifications in the Emirate of Dubai	The purpose of the regulations is to improve the performance of buildings in Dubai by reducing the consumption of energy, water and materials, improving public health, safety and general welfare and by enhancing the planning, design, construction and operation of buildings to create an excellent city that provides the essence of success and comfort of living.

Codes and Standards Related to Lighting

All lighting codes and standards located in the above two documents appear to be applicable to both residential and commercial buildings. Text was taken directly from the documents without paraphrasing where suitable.

Lighting Power Densities

Section 502.04 of the Green Building regulations provides a table of **interior lighting power densities** for commercial buildings; lighting power densities for building types not listed in Table 502.04 (1) should be no greater than those values given in ASHRAE 90.1-2007 Table 9.5.1.or equivalent as approved by DEWA.

Section 502.05 of the Green Building regulations provides a table of **exterior lighting power densities**, with relevant residential building areas listed below.

Building area	Maximum watts per square meter	
	Value	Units
Uncovered parking lots and drives	1.6	W/m^2
Walkways less than 3 meters wide	3.3	W/linear meter
Walkways 3 m wide or greater	2.2	W/m^2
Outdoor stairways	10.8	W/m^2
Main entries	98	W/linear meter of door width
Other doors	66	W/linear meter of door width

Natural Lighting

Section 405.01 of the Green Building regulations provides a provision for natural daylight:

- For all new buildings, other than industrial buildings, provision for adequate natural daylight must be made in order to reduce their reliance on electrical lighting and to improve conditions for the building occupants and provide lighting openings in accordance with Dubai municipality building regulation and specification.

Article 12 of the Dubai Municipality regulations states the following information for **natural lighting and ventilation openings**:

- For all rooms, halls, lobbies, corridors, staircases, kitchens, bathrooms in any building, natural lighting and ventilation stipulated in Article 13, as well as secondary ventilation, shall be provided.
- Natural lighting and ventilation may be replaced by artificial lighting and ventilation for toilets, bathrooms, pantries of area less than minimum area for kitchens, corridors, halls and

rooms some specialized projects that require the alternative, provided that the approval of the competent department shall be obtained and requirements for mechanical lighting and ventilation shall be fulfilled.

- Lighting intensity in the various parts of a building shall satisfy the requirement stipulated in the approved standard specifications. Internal air in the building shall, in terms of quantity and quality, satisfy the environment and public health requirements applicable in the UAE.

Article 13 of the Dubai Municipality regulations states the following information for **window openings**:

- Each room, residential or otherwise, and each staircase chute or kitchen or hall or corridor, shall be provided with an opening for lighting and ventilation of not less than an overall area of 10% of the overall room, 5% of the service area (kitchens, bathrooms, toilets, stores, staircases).
- Lighting and ventilation openings, in the same percentages stapled in the above item, may be cut in the roof, provided that such openings shall lead directly into the external air and the part in which such openings shall be cut, shall not be allocated for bedrooms, and a mechanical opening device be fitted on such openings at a level of 3 feet above the floor.
- The main staircase of the building shall be provided with lighting and ventilation openings n each floor level effective from the first floor upwards until the highest level.
- Natural lighting and ventilation openings of not less than 5% of the floor area, shall be provided in the warehouses and workshops. Warehouse gate / door openings shall form part of these lighting and ventilation openings.

Article 14of the Dubai Municipality regulations states the following information for **chutes and yards**:

Natural lighting and ventilation requirements for functional uses overlooking the chute, shall be as follows:

- Bathrooms: The area of the chute shall not be less than 9 square feet and its width shall not be less than 3 feet. Requirement for natural lighting and ventilation may be waived in case an integral system for lighting and mechanical ventilation shall be provided as per approved specifications available at the competent department. Natural lighting requirements may be waived if the necessary artificial lighting shall be provided as per approved specifications applicable at the competent department.
- A chute is defined as “space open to sky and surrounded by buildings on three or more sides. Only utilities would overlook it.” An inner yard is defined as “space open to sky and surrounded by buildings on three or more sides and has rooms of one or more residential or office units overlooking it.”

Article 21of the Dubai Municipality regulations states the following information for **staircases**:

- The main staircase in the residential, commercial and public buildings shall be made of fire resistant material (except for villas). Natural ventilation and lighting shall be provided in an adequate manner in staircases through windows that open directly to the outside sky or to the chute. Staircases for towers in excess of (10) floors shall be exempted from the requirement for natural ventilation and lighting, provided that the mechanical ventilation and artificial lighting shall be provided as per the requirements of the safety and fire-fighting regulations.

Light Pollution

Section 303.01 of the Green Building regulations discusses exterior light pollution and controls:

- For all new buildings, permanently installed exterior lighting must comply with the following:

    1. All exterior light fixtures on the building site, other than architectural accent lighting and Civil Aviation safety lighting, must be shielded so that all of the light emitted by the fixture, either directly or indirectly by reflection or refraction from any part of the fixture, is projected below the horizontal plane passing through the lowest part of the fixture;
    2. Architectural accent lighting must be aimed or shielded to prevent the lighting of the night sky. Wall washing lights must spill no more than 10% of the lighting past the building façade;
    3. Downward directed lighting must be used for lighting of signage; and
    4. All exterior lighting must be fitted with automatic controls to ensure that lights do not operate during daylight hours.

Appendix III

Summary of Lighting Codes and Standards for Abu Dhabi Emirate

Summary of Codes and Standards Reviewed

Code/Standard	Purpose
Accessible and Usable Buildings and Facilities (Abu Dhabi/ICC A117.1-2009)	This standard provides building criteria to ensure that people with physical disabilities can independently get to, enter, and use a site, facility, building, or element.
Abu Dhabi International Building Code	This code establishes the minimum requirements for structural strength, egress, stability, sanitation, adequate light/ventilation, energy conservation, and safety of buildings.
Abu Dhabi International Energy Conservation Code	This code regulates the design and construction of residential and commercial buildings for the effective use of energy.
Abu Dhabi International Fuel Gas Code	This code applies to the installation of fuel-gas piping systems, fuel gas appliances, gaseous hydrogen systems, and related accessories.
Abu Dhabi International Mechanical Code	This code regulates the design, installation, maintenance, alteration, and inspection of mechanical systems and equipment involved in controlling environmental conditions inside buildings.
Abu Dhabi International Property Maintenance Code	This code applies to all existing residential and non-residential structures and premises. It provides minimum requirements for light, ventilation, space, heating, sanitation, and safety.
Abu Dhabi International Private Sewage Disposal Code	This code provides minimum standards for the design, construction, installation, material quality, location, operation, maintenance, and use of private sewage disposal systems.

Summary of Documents Reviewed

Code/Standard	Purpose
Estidama Pearl Building Rating System (PBRS) – RE-R1 Energy Prescriptive Pathway document from July 2011.	This document is based on selected requirements from the Abu Dhabi International Energy Conservation Code. It provides a summary of the requirements relating to envelope, systems, lighting, and renewables.
The Pearl Rating System for Estidama – Building Rating System Design and Construction, Version 1.0, April 2010	The Pearl Rating System for Estidama aims to address the sustainability of a given development throughout itslifecycle from design through construction to operation. The Pearl Rating System provides design guidance anddetailed requirements for rating a project's potential performance in relation to the four pillars of Estidama.

Summary of All Codes/Standards Related to Lighting

Residential Lighting Codes

Illuminance Levels

Code/Standard	Element Being Illuminated	Illuminance Levels
A117.1-2009, 409.4.5 Illumination	Elevator car controls, platform, and car threshold and landing sill	5 foot-candles (54 lux) minimum
A117.1-2009, 504.8.1 Illumination Level	Steps on stairs	10 foot-candles (108 lux) of illuminance measured at the center of tread surfaces and on landing surfaces within 24 inches (610 mm) of step nosings

Interior Lighting Power Density (W/m^2)

From the Estidama Pearl Building Rating System (PBRS) – RE-R1 Energy Prescriptive Pathway (July 2011). All internal lighting systems are to have a lighting power density less than the target value for the relevant zone type in the following table:

	Whole Building	Space by Space
Dining: Family	15.5	
Dining		13.6
Kitchen		11.6
Dormitory	9.7	
Living Quarters		10.7
Bedroom		4.8
Study Hall		13.6
Multi-Family	6.8	

Exterior Lighting

From the Estidama Pearl Building Rating System (PBRS) – RE-R1 Energy Prescriptive Pathway (July 2011). The total exterior lighting power for the building is to be less than the sum of the individual lighting power densities permitted for the relevant applications considered. Trade-offs are permitted between the applications listed under the Tradable Surfaces section. All external lighting applications under the Non-tradable Surfaces must comply with the lighting power specified.

Applications	Lighting Power Densities	
	Value	Units
Parking lots and drives	1.45	W/m^2
Walkways less than 3 meters wide	2.95	W/linear meter
Walkways 3 m wide or greater	1.94	W/m^2
Stairways	9.69	W/m^2
Main entrances	88.6	W/linear meter of door width
Other doors	59.1	W/linear meter of door width

All surfaces listed are tradable.

Lighting

The Abu Dhabi International Property Maintenance Code provides the following information on residential lighting:

402.1 Habitable spaces. Every habitable space shall have at least one window of approved size facing directly to the outdoors or to a court. The minimum total glazed area for every habitable space shall be 8 percent of the floor area of such room. Wherever walls or other portions of a structure face a window of any room and such obstructions are located less than 3 feet (914 mm) from the window and extend to a level above that of the ceiling of the room, such window shall not be deemed to face directly to the outdoors nor to a court and shall not be included as contributing to the required minimum total window area for the room.

Exception: Where natural light for rooms or spaces without exterior glazing areas is provided through an adjoining room, the unobstructed opening to the adjoining room shall be at least 8 percent of the floor area of the interior room or space, but not less than 25 square feet (2.33 m^2). The exterior glazing area shall be based on the total floor area being served.

402.2 Common halls and stairways. Every common hall and stairway in residential occupancies, other than in one- and two-family dwellings, shall be lighted at all times with at least a 60-watt standard incandescent light bulb for each 200 square feet (19 m^2) of floor area or equivalent illumination, provided that the spacing between lights shall not be greater than 30 feet (9144 mm). In other than residential occupancies, means of egress, including exterior means of egress, stairways shall be illuminated at all times the building space served by the means of egress is occupied with a minimum of 1 foot-candle (11 lux) at floors, landings and treads.

402.3 Other spaces. All other spaces shall be provided with natural or artificial light sufficient to permit the maintenance of sanitary conditions, and the safe occupancy of the space and utilization of the appliances, equipment and fixtures.

Recessed Lighting

The Abu Dhabi International Energy Conservation Code provides the following information on recessed lighting for residences:

402.4.5 Recessed lighting. Recessed luminaires installed in the building thermal envelope shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and labeled as meeting ASTM E 283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the conditioned space to the ceiling cavity. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

404.1 Lighting equipment. A minimum of 50 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps.

Chapter 2 of the Abu Dhabi International Energy Conservation Code defines high-efficacy lamps as: Compact fluorescent lamps, T-8 or smaller diameter linearfluorescent lamps, or lamps with a minimum efficacy of:

1. 60 lumens per watt for lamps over 40 watts,
2. 50 lumens per watt for lamps over 15 watts to 40 watts, and
3. 40 lumens per watt for lamps 15 watts or less.

Lighting Codes Applicable to All Buildings (Residential and Non-Residential)

Elevator Illumination

Section A117.1-2009 provides requirements under 407.4.5, 408.4.5, and 409.4.5 for illumination within elevators. These sections state the following:

- **407.4.5 Illumination.** The level of illumination at the car controls, platform, car threshold and car landing sill shall comply with ASME A17.1/CSA B44 listed in Section 105.2.5.
- **408.4.5 Illumination.** Elevator car illumination shall comply with Section 407.4.5.
- **409.4.5 Illumination.** The level of illumination at the car controls, platform, and car threshold and landing sill shall be 5 foot-candles (54 lux) minimum.

Stairwell Illumination

Section A117.1-2009 provides requirements under 504.8, 504.8.1, and 504.8.2 for illumination within stairwells. These sections state the following:

- **504.8 Lighting.** Lighting for interior stairways shall comply with Section 504.8.
- **504.8.1 Illumination Level.** Lighting facilities shall be capable of providing 10 foot-candles (108 lux) of illuminance measured at the center of tread surfaces and on landing surfaces within 24 inches (610 mm) of step nosings.

- **504.8.2 Lighting Controls.** If provided, occupancy-sensing automatic controls shall activate the stairway lighting so the illuminance level required by Section 504.8.1 is provided on the entrance landing, each stair flight adjacent to the entrance landing, and on the landings above and below the entrance landing prior to any step being used.

Additions, Alterations, Renovations, or Repairs

The Abu Dhabi International Energy Conservation Code provides the following information on lighting:

- **101.4.3 Additions, alterations, renovations or repairs.** Additions, alterations, renovations or repairs to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion(s) of the existing building or building system to comply with this code. Additions, alterations, renovations or repairs shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code if the addition alone complies or if the existing building and addition comply with this code as a single building.
- **Exception:** The following need not comply provided the energy use of the building is not increased:
  7. Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.
  8. Alterations that replace only the bulb and ballast within the existing luminaires in a space provided that the alteration does not increase the installed interior lighting power.
- **101.4.4 Change in occupancy or use.** Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code. Where the use in a space changes from one use in Table 505.5.2 to another use in Table 505.5.2, the installed lighting wattage shall comply with Section 505.5.

Summary of Non-Residential Lighting Codes

The **Abu Dhabi International Building Code** provides information on auditorium lighting and illumination of means of egress in 409.4 and 403.5.5. It also mentions that during emergencies, the activation of smoke detectors, sprinkler system, or other approved fire detection device should cause illumination of the means of egress with light of at least 1 foot-candle (11 lux) at the walking surface level (907.2.12.2). This illumination requirement is also mentioned in 1006.2 for means of egress lighting, and is the same in 3007.3 for hoistway lighting, as measured from the top of the car of each fire service access elevator.

The **Abu Dhabi International Energy Conservation Code** provides information on the installation of commercial recessed lighting at 502.4.8. It also provides several pages of information on lighting system controls, the maximum lighting power for interior applications, and the minimum acceptable lighting equipment for exterior applications (Section 505). In addition, there is a table of lighting power density values in watts/ft^2 for different commercial building types, which appears to have been adopted from ASHRAE 90.1.

The **Abu Dhabi International Property Maintenance Code** states that every public hall, interior stairway, toilet room, kitchen, bathroom, laundry room, boiler room and furnace room shall contain at least one electric luminaire (605.3).

Appendix IV

Voluntary Survey

EMIRATES WILDLIFE SOCIETY
VOLUNTARY SURVEY OF RESIDENTIAL LIGHTING
(Long version)

GENERAL INFORMATION ABOUT RESIDENCE

What type of residence do you live in?
(Check one of the boxes below)

☐ Villa ☐ Flat/Apartment ☐ Other

If other, please describe:

____

In which Emirate is your residence located?
(Check one of the boxes below)

☐ Abu Dhabi ☐ Ajman ☐ Dubai ☐ Fujairah
☐ Ras al Khaimah ☐ Sharjah ☐ Umm al Quwain

What is the name of the city or region where your residence is located?

____

When was your residence constructed?
(Check one of the boxes below)

☐ After 2000 ☐ Between 1990 and 2000 ☐ Before 1990

Who is responsible for replacing burned out lamps in your residence?
(Check one of the boxes below)

☐ Member of household ☐ Property manager or other person

Instructions for Completing the
INTERIOR LUMINAIRE AND LAMP DATA FORM

1. Please complete the form for each luminaire in each room of your residence. Do not use this form for data on garage and exterior lighting; a separate form is provided for those uses.

2. This form can accommodate up to three luminaires, so you will need to make additional copies of the form to cover all the luminaires in your residence.

3. Enter the type of room in the space provided. Please select one of the following room types: bedroom, kitchen, washroom, dining room, living room, hallway, other.

4. For each luminaire in the room, indicate the name or a brief description of the luminaire. For example: ceiling light, chandelier, table lamp, torchière.

5. Check one of the boxes to indicate if the luminaire is a *built in* luminaire or is a *plug in*luminaire. *Built in* luminaires are usually mounted in the ceiling or are suspended from the ceiling and are turned on using a wall switch. *Plug in* luminaires typically must be plugged into a wall socket (electrical outlet) and are turned on using a switch mounted on the luminaire itself.

6. Select which type of lamp is used in the luminaire and enter the information requested below the appropriate lamp picture. The pictures and characteristics on the following pages can help to identify the type of lamp. Note that there may be several designs for a specific type of lamp, as shown in the pictures. Also, the pictures are not to scale and do not provide an indication of the relative size of the lamp. If you are not sure what the lamp type is, make your best guess, or check the box for "Not Sure."

7. Below the picture on the form, enter the number of lamps in the luminaire.

8. Indicate the relative brightness of the lamps by checking one of the boxes. Select *Dim* if the individual lamps in the luminaire are relatively dim or they are not as bright as most lamps in your residence. Select *Moderate* if the lamps are moderately bright. Select *Bright* if the lamps are brighter than most of the indoor lamps in your residence. If you know the wattage (i.e., how many watts each lamp uses), the following guide can also be used in determining the relative brightness:

Lamp Type	**Dim**	**Moderate**	**Bright**
Incandescent	less than 40 watts	40 to 60 watts	more than 60 watts
CFL	less than 12 watts	12 to 19 watts	more than 19 watts
Halogen	less than 30 watts	31 to 50 watts	more than 50 watts
LED	less than 15 watts	16 to 21 watts	more than 21 watts

9. If you can determine how many watts a lamp uses, enter the wattage in the blank provided. If you cannot determine the wattage, do not enter any values. On most lamps, the wattage is imprinted on the lamp itself and is abbreviated using a "W" (for example, "60W" means a 60-watt lamp).

Compact Fluorescent Light (CFL) Lamps

CFL Lamp Characteristics:

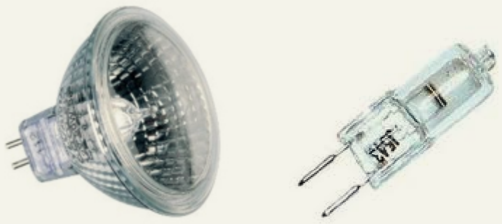
- The lamp element is either spiral or U-shaped. (Note: some decorative CFL lamps may have an outer glass globe that surrounds the element.)
- After turning on the luminaire, there may be a slight delay before the lamp reaches it full brightness.
- The lamp may flicker when turned on.
- The light emitted is either pure white or has a light blue tint.
- The lamp does not become very hot.

Incandescent Lamps

Incandescent Lamp Characteristics

- The lamp reaches its full brightness immediately after the luminaire is turned on.
- The lamp may have a clear glass globe, inside of which there is a glowing wire element.
- The light emitted may have an orange or red tint.
- The lamp becomes very hot.

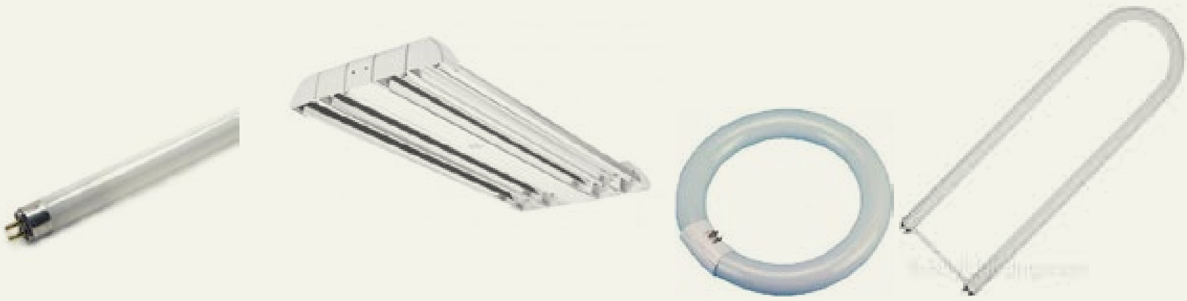
Halogen Lamps



Halogen Lamp Characteristics

- The lamp is generally small (e.g., smaller than most CFL or incandescent lamps).
- The light emitted is much more intense than most lamps.
- Halogen lamps are often used in track lights or spot lights that are designed to illuminate a specific area of a room rather than for providing general lighting.
- The light emitted is pure white.
- The lamp becomes very hot.

Linear Fluorescent Lamps



Linear Fluorescent Lamp Characteristics

- It should be apparent from the shape if the lamp is linear fluorescent.
- The most common types are tube-shaped lamps that are 50 cm to 120 cm long.
- Most of the other characteristics are similar to those for CFL lamps.

Light-Emitting Diode (LED) Lamps

LED Characteristics

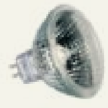
- Many LED lamps have several small elements that are very bright.
- The light may have a blue tint, but red tints are also possible.
- The lamp may have exterior sections that are yellow in color when not energized.
- The lamp does not become very hot, although the outside may be warm to the touch.

INTERIOR LUMINAIRE AND LAMP DATA FORM
(Complete this form for each luminaire in each room of your residence.)

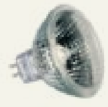
Type of Room: ______________________________
Type of Luminaire: ___________________________ ☐ Built in ☐ Plug in

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					?
Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____

Type of Room: ______________________________
Type of Luminaire: ___________________________ ☐ Built in ☐ Plugin

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					?
Number: ___ ☐ Dim ☐ Moderate ☐Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____

Type of Room: ______________________________
Type of Luminaire: ___________________________ ☐ Built in ☐ Plug in

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					?
Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐Moderate ☐ Bright Watts: ____

Instructions for Completing the
EXTERIOR LUMINAIRE AND FLOODLIGHT DATA FORM

1. This form should be completed if you live in a villa. If you live in an apartment or any other type of housing unit, you do not need to complete the form.

2. Please complete the form for each luminaire or floodlight that is located outside your villa, but on your property. If you have a garage, you should enter the information on garage lighting on this form.

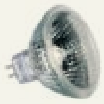
3. The form can accommodate up to three luminaires or floodlights, so you will need to make additional copies of the form if you have more than three exterior luminaires or floodlights.

4. Describe the location of the luminaire/floodlight in the space provided.

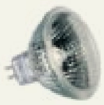
5. For lamp data, follow the same procedures that you used to complete the INTERIOR LUMINAIRE AND LAMP DATA FORM.

EXTERIOR LUMINAIRE AND FLOODLIGHT DATA FORM
(If you live in a villa, please complete this form for each luminaire or floodlight that is located on your property, but outside of your residence.)

Location of Luminaire or Floodlight: ______________________________

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					**?**
Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____

Location of Luminaire or Floodlight: ______________________________

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					**?**
Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____

Location of Luminaire or Floodlight: ______________________________

Incandescent	CFL	Halogen	Linear Fluorescent	LED	Not Sure
					**?**
Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____	Number: ___ ☐ Dim ☐ Moderate ☐ Bright Watts: ____

Appendix V

Voluntary Residential Lighting Survey: Complete Results

Summary of Voluntary Residential Lighting Survey – Interior Lighting

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1794340345	villa	Abu Dhabi	Before 1990	Member of household							
1794440681	villa	Abu Dhabi	Between 1990 and 2000	Property manager or other person							
1797715078	villa	Abu Dhabi	After 2000	Property manager or other person							
1797750972	villa	Dubai	After 2000	Member of household							
1797772800	villa	Dubai	Between 1990 and 2000	Member of household							
1797779850	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	60
1797779850	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	2	Moderate	60
1797779850	villa	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	16	Bright	
1797943995	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1797943995	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1797943995	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	1		
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	12	Bright	
1797948965	villa	Abu Dhabi	After 2000	Member of household							
1797949414	villa	Abu Dhabi	After 2000	Property manager or other person							
1797949827	villa	Abu Dhabi	After 2000	Property manager or other person							
1797966696	villa	Abu Dhabi	After 2000	Member of household							

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797967091	villa	Dubai	After 2000	Member of household							
1797987374	villa	Dubai	Between 1990 and 2000	Member of household							
1797996992	villa	Dubai	Between 1990 and 2000	Member of household							
1798349616	villa	Dubai	After 2000	Member of household							
1798366458	villa	Dubai	After 2000	Property manager or other person							
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	10	Bright	
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	14	Bright	
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen	Incandescent			8		40
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Moderate	40
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Bathroom	CFL	Ceiling light	Plug In	1	Dim	40
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	1	Dim	40
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	5	Moderate	40
1799369514	villa	Dubai	After 2000	Member of household	Kitchen	Incandescent			6		
1799369514	villa	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	6	Bright	360
1799369514	villa	Dubai	After 2000	Member of household	Bedroom	LED	Ceiling light	Built In	12	Moderate	150W
1799369514	villa	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	12	Bright	200W

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1799369514	villa	Dubai	After 2000	Member of household	Living Room	LED	Ceiling light	Built In	12	Moderate	100W
1799369514	villa	Dubai	After 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light		6	Moderate	200
1799461299	villa	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	6	Moderate	
1799461299	villa	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Built In	8	Bright	
1799461299	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Bright	
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Hallway	Incandescent	Ceiling light	Plug In	10	Moderate	60W each
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Hallway	Linear Fluorescent	Ceiling light	Built In	13	Moderate	40
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Hallway	Halogen	Ceiling light	Plug In	3	Bright	
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Hallway	Incandescent	Ceiling light	Plug In	1	Moderate	60
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	9	Moderate	40
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In	5	Moderate	60
1799528681	villa	Sharjah	After 2000	Property manager or other person							
1800714352	villa	Sharjah	Between 1990 and 2000	Member of household							
1802727392	villa	Dubai	After 2000	Property manager or other person							
1803992862	villa	Abu Dhabi	Between 1990 and 2000	Member of household							
1806503566	villa	Abu Dhabi	Before 1990	Member of household	Living Room	CFL	Ceiling light	Plug In	2	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1806503566	villa	Abu Dhabi	Before 1990	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	
1806503566	villa	Abu Dhabi	Before 1990	Member of household	Kitchen	CFL	Ceiling light	Plug In	1	Moderate	
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	2	Moderate	40 to 60
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Not Sure	Ceiling light	Built In	2	Moderate	40 to 60
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	LED	Ceiling light	Built In	1	Moderate	16 to 21
1805625734	villa	Dubai	After 2000	Member of household							
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Halogen		Built In	1	Moderate	31 to 50
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Built In	1	Moderate	12 to 19
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	1	Moderate	40 to 60
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Not Sure	Ceiling light	Built In	1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	LED	Ceiling light	Built In	1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light		1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	1	Moderate	12 to 19
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Halogen	Ceiling light	Built In	1	Moderate	31 to 50
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	1	Moderate	40 to 60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	LED	Ceiling light	Built In	1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	1	Moderate	31 to 50
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	1	Moderate	12 to 19
1808308432	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	2	Moderate	15
1808308432	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	3	Moderate	15
1808308432	villa	Abu Dhabi	After 2000	Property manager or other person	Bathroom	CFL	Ceiling light	Built In	2	Moderate	15
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Living Room	CFL	Ceiling light	Plug In	10	Moderate	19
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Living Room	Linear Fluorescent	Ceiling light	Plug In	20	Moderate	21
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Bedroom	CFL	Chandelier	Plug In	8	Moderate	19
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Plug In	10	Moderate	21
1807529325	villa	Dubai	Before 1990	Member of household							
1808039777	villa	Sharjah	After 2000	Property manager or other person							
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Dining room	CFL	Chandelier	Plug In	5	Moderate	19
1810784397	villa	Abu Dhabi	Before 1990	Member of household	Dining room	Linear Fluorescent	Ceiling light	Plug In	6	Moderate	21
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	1	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	CFL	Table light	Plug In	1	Dim	
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	2	Bright	
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Table light	Plug In	2	Moderate	
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Chandelier	Built In	10	Moderate	40
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Not Sure	Table light		5		
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Chandelier	Built In	30	Moderate	40
1810776393	villa	Abu Dhabi	Before 1990	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Plug In	2	Bright	21
1797943995	villa	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Plug In		Moderate	
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Chandelier	Built In		Bright	
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	CFL	Chandelier				
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Table light				
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	wall sconce				
1810811269	villa	Abu Dhabi	Before 1990	Member of household							
1799369514	villa	Dubai	After 2000	Member of household	Bedroom	CFL	Table light	Plug In		Dim	40
1803818687	Studio	Abu Dhabi		Property manager or other person	Bedroom						
1803818687	Studio	Abu Dhabi		Property manager or other person	Bathroom						

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1803818687	Studio	Abu Dhabi		Property manager or other person	Living Room						
1797651042	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Incandescent	Table light	Plug In	1	Dim	10
1797651042	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Built In	6	Moderate	
1797651042	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen						
1797651042	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bathroom						
1797652635	Flat/ Apartment	Dubai	After 2000	Member of household							
1797663026	Flat/ Apartment	Dubai	After 2000	Member of household							
1797665222	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person							
1797668904	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1797670661	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	4	Moderate	60
1797670661	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	4	Moderate	60
1797670661	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Table light	Plug In	2	Moderate	30
1797670661	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Halogen	Ceiling light	Built In	2	Moderate	30
1797680572	Flat/ Apartment	Dubai	After 2000	Member of household		Halogen	Ceiling light	Built In	2	Moderate	60
1797712349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	50
1797712349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	1	Moderate	50

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797712349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom						
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Not Sure		Plug In			
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	LED	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Halogen	Chandelier				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Chandelier				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent	Table light	Built In			
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	LED	Chandelier				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Linear Fluorescent	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Halogen	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	LED	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Halogen	Table light				
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light				
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bathroom	CFL	Ceiling light	Built In	1	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bathroom	Not Sure	Ceiling light	Built In	2	Bright	
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	2	Bright	
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Dining room	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1797816515	Flat/ Apartment	Sharjah	After 2000	Property manager or other person							
1797881619	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Moderate	60
1797881619	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	8	Bright	60
1797881619	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	1		60
1797927144	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Hallway	CFL	Ceiling light	Built In	5	Moderate	
1797927144	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Chandelier	Built In	8	Bright	
1797927144	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Incandescent	Ceiling light	Built In	2	Moderate	
1797927144	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Linear Fluorescent	Ceiling light	Built In	1	Moderate	
1797965756	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	4	Moderate	60
1797965756	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	LED	Ceiling light	Plug In	2	Bright	80
1797965756	Flat/ Apartment	Sharjah	After 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In	1	Dim	40
1797965756	Flat/ Apartment	Sharjah	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	1	Moderate	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Table light	Plug In	1	Moderate	40
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	less 40
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Halogen	Ceiling light	Built In	4	Bright	
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	16	Moderate	less 40
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Hallway	Halogen	Ceiling light	Built In	6	Bright	40
1797989469	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	10	Bright	100
1797989469	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light				
1797989469	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Halogen			4	Bright	60
1797989469	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	4	Bright	100
1797990962	Flat/ Apartment	Dubai	Before 1990	Member of household							
1798010396	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	3	Dim	
1798010396	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	2	Dim	
1798010396	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	1	Moderate	
1798010396	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	3	Dim	
1798044271	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person							
1798046433	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	3	Moderate	40

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798046433	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In		Moderate	
1798046433	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1798050480	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	6	Moderate	100
1798050480	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Not Sure	Ceiling light	Built In	6	Moderate	100
1798050480	Flat/ Apartment	Dubai	After 2000	Member of household	Dining room	Not Sure	Ceiling light	Built In	6	Moderate	100
1798310172	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household							
1798326391	Flat/ Apartment	Dubai	After 2000	Member of household							
1798336898	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	2	Moderate	
1798336898	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	4	Moderate	
1798336898	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	4	Moderate	
1798337129	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	6	Moderate	12
1798337129	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Moderate	
1798337129	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	3	Moderate	12
1798339462	Flat/ Apartment	Dubai	After 2000	Member of household							
1798343694	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Moderate	15
1798343694	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	6	Moderate	10

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798343694	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	6	Moderate	10
1798351724	Flat/ Apartment	Ajman	After 2000	Member of household	Living Room	CFL	Ceiling light	Plug In	2	Bright	22
1798351724	Flat/ Apartment	Ajman	After 2000	Member of household	Kitchen	CFL	Ceiling light	Plug In	2	Bright	18
1798351724	Flat/ Apartment	Ajman	After 2000	Member of household	Bedroom	CFL	Ceiling light	Plug In	2	Moderate	18
1798362552	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	2	Dim	<40w
1798362552	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Chandelier	Built In	5	Moderate	18w
1798362552	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	4	Moderate	18w
1798362552	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	2	Moderate	18w
1798364376	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Plug In	6	Moderate/ Bright	60
1798364376	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Plug In	12	Moderate/ Bright	60
1798364376	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Incandescent	Ceiling light		2	Moderate	60
1798366689	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Chandelier	Built In	6	Bright	40
1798366689	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Chandelier	Built In	6	Bright	40
1798366689	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Bright	40
1798374805	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	CFL	Ceiling light	Plug In	1	Bright	40
1798374805	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Halogen	Table light	Plug In	1	Bright	10

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798374805	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	CFL	Ceiling light	Plug In	2	Bright	20
1798374805	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bathroom	Incandescent	Chandelier	Plug In	2	Moderate	20
1798383030	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household							
1798480379	Flat/ Apartment	Dubai	After 2000	Member of household							
1798480559	Flat/ Apartment	Dubai	After 2000	Member of household							
1798536298	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	40
1798536298	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	2	Moderate	40
1798536298	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In	1	Moderate	40
1798597279	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	1	Moderate	60W
1798597279	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	CFL	Ceiling light	Plug In	2	Bright	60W
1798606251	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1798633086	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	1	Bright	
1798633086	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	
1798633086	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Plug In	2	Moderate	40
1798633086	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Plug In	7	Moderate	40
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Plug In	2	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Not Sure	Ceiling light				
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In	2	Moderate	
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Plug In	1	Moderate	
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Plug In	1	Moderate	
1799057904	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	Incandescent		Built In			
1799057904	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light		4	Bright	60
1799057904	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	5	Moderate	60
1799057904	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	60
1799155474	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	2	Moderate	
1799155474	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1799155474	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	2	Dim	
1799600630	Flat/ Apartment	Sharjah	After 2000	Member of household							
1799950389	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Incandescent		Built In/ Plug In			
1799950389	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In		Moderate	
1800108762	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Moderate	40
1800108762	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	6	Moderate	40

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1800108762	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Built In	7	Moderate	40
1800190160	Flat/ Apartment	Sharjah	After 2000	Member of household							
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Plug In	2	Moderate	40
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Not Sure			2		
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	LED	Ceiling light	Built In	2	Moderate	60
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	2	Moderate	40
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Halogen	Ceiling light	Built In	1		100
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	2	Moderate	30
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent			2		50
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	2	Moderate	50
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household	Hallway	CFL	Ceiling light	Built In	1	Moderate	40
1800274870	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person							
1800283944	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person							
1800287392	Flat/ Apartment	Sharjah	After 2000	Member of household							
1800332905	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	1	Moderate	60
1800332905	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	1	Bright	100

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1800367376	Flat/ Apartment	Fujairah	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In		Moderate	
1800367376	Flat/ Apartment	Fujairah	After 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In		Moderate	
1800367376	Flat/ Apartment	Fujairah	After 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In		Bright	
1800425699	Flat/ Apartment	Sharjah	After 2000	Property manager or other person							
1801125718	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In		Dim	8
1801125718	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	4	Bright	40
1801125718	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Incandescent	Chandelier	Built In	1	Dim	8
1801125718	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	2	Moderate	20
1801266152	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	1	Moderate	
1801266152	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	1	Moderate	
1801266152	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1801266152	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Living Room	CFL	Chandelier	Built In	5	Bright	
1801542626	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	7	Bright	
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Halogen	Ceiling light	Built In	2	Bright	
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Chandelier	Built In	6	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Halogen	Ceiling light	Built In	1	Bright	
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Incandescent		Built In			
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Linear Fluorescent	Side wall	Built In	1	Bright	
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	CFL	Ceiling light	Built In	2	Bright	
1802012579	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Chandelier	Built In	2	Bright	100
1802012579	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Table light	Plug In	3	Dim	40
1802012579	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Hallway	Halogen	Ceiling light	Built In	2	Bright	100
1802035119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Incandescent		Built In			
1802035119	Flat/ Apartment	Dubai	After 2000	Property manager or other person		Linear Fluorescent	Ceiling light	Built In	4	Bright	40
1802035119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Chandelier	Built In	2	Moderate	40
1802035119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Chandelier	Built In	3	Moderate	40
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	1	Bright	40
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Moderate	18 each
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	2	Bright	100W each
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Table light	Plug In	3	Moderate	18W each
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	1	Bright	150W

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Table light	Plug In	1	Moderate	18
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	10	Bright	
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Table light	Plug In	4	Dim	
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Chandelier	Built In	6	Bright	
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Table light	Plug In	2	Moderate	
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	2	Moderate	
1802107185	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1802121169	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household							
1802413548	Flat/ Apartment	Dubai	After 2000	Member of household							
1802624378	Flat/ Apartment	Dubai	After 2000	Member of household							
1803061121	Flat/ Apartment	Dubai	After 2000	Member of household							
1803338902	Flat/ Apartment	Sharjah	After 2000	Member of household							
1803776244	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	60
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Incandescent		Built In	4	Moderate	
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Not Sure	Ceiling light	Built In	2	Bright	
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	2	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Not Sure	Chandelier	Built In	4	Moderate	
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In		Dim	
1803795077	Flat/ Apartment	Umm al Quwain	Before 1990	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In	2	Moderate	60
1803795077	Flat/ Apartment	Umm al Quwain	Before 1990	Property manager or other person	Living Room	Incandescent	Chandelier	Built In	2	Bright	
1803795077	Flat/ Apartment	Umm al Quwain	Before 1990	Property manager or other person	Dining room	CFL	Ceiling light	Plug In	2	Moderate	60
1803795446	Flat/ Apartment	Dubai	Before 1990	Member of household							
1803829348	Flat/ Apartment	Ajman	After 2000	Member of household	Living Room	CFL	Chandelier	Built In	6	Bright	26
1803829348	Flat/ Apartment	Ajman	After 2000	Member of household	Hallway	Halogen	Ceiling light	Built In	3	Bright	60
1803829348	Flat/ Apartment	Ajman	After 2000	Member of household	Hallway	Linear Fluorescent	Ceiling light	Built In	1	Bright	32
1803829348	Flat/ Apartment	Ajman	After 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Bright	32
1803831117	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Plug In	6	Moderate	26
1803831117	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Hallway	CFL	Ceiling light	Plug In	3	Dim	16
1803831117	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	CFL	Ceiling light	Plug In	2	Dim	16
1803831789	Flat/ Apartment	Ras Al Khaimah	Between 1990 and 2000	Property manager or other person							
1803855995	Flat/ Apartment	Dubai	Before 1990	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	1	Moderate	120
1803855995	Flat/ Apartment	Dubai	Before 1990	Member of household	Kitchen	Not Sure	Ceiling light	Built In	1	Moderate	120

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1803855995	Flat/ Apartment	Dubai	Before 1990	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	1	Moderate	120
1803855995	Flat/ Apartment	Dubai	Before 1990	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In		Moderate	120
1803879890	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1803879890	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	2	Bright	
1803879890	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	2	Moderate	
1803885727	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	6	Bright	
1803885727	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen	Not Sure	Ceiling light	Built In	6	Bright	
1803885727	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	4	Bright	
1803885727	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bathroom	Not Sure	Ceiling light	Built In	1	Moderate	
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	40
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	1	Moderate	20
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	2	Moderate	40
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	1		20
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bathroom	CFL	Ceiling light	Built In	1	Moderate	20
1804245792	Flat/ Apartment	Dubai	Before 1990	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	4	Moderate	
1804245792	Flat/ Apartment	Dubai	Before 1990	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1804245792	Flat/ Apartment	Dubai	Before 1990	Member of household	Bedroom	CFL	Chandelier	Built In	2	Moderate	60
1804435616	Flat/ Apartment	Dubai	After 2000	Member of household							
1804468287	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person							
1804652614	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person							
1804805528	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Plug In	3	Bright	5W
1804805528	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Plug In	3	Moderate	3
1804805528	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Dining room	Halogen	Table light	Built In	4	Moderate	3
1805780267	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	12	Bright	18
1805891056	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Plug In	2	Moderate	60
1805780267	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Chandelier	Plug In	3	Moderate	11
1805780267	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Chandelier	Plug In	10	Bright	11
1805854096	Flat/ Apartment	Dubai	After 2000	Member of household							
1805891056	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Halogen	Ceiling light	Built In	4	Bright	100
1807326425	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	5	Dim	40
1805891056	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Halogen	Ceiling light	Built In	1	Moderate	60
1805891056	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	1	Bright	100

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1805927117	Flat/ Apartment	Dubai	After 2000	Member of household							
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household	Dining room	Incandescent	Ceiling light	Built In	6	Moderate	40
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household	Dining room	Halogen				Bright	
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	3	Bright	100
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Halogen	Ceiling light	Built In	3	Bright	unsure
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Bright	unsure
1806642517	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Plug In	1	Moderate	
1806642517	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	
1806642517	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Dining room	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	
1807262962	Flat/ Apartment	Dubai	After 2000	Member of household							
1807326425	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	1	Bright	
1807746078	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	21	Moderate	
1807326425	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	3	Dim	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	Not Sure		Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	LED	Ceiling light	Plug In	3	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	Linear Fluorescent	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	Halogen	Ceiling light	Plug In	1	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	CFL	Ceiling light	Plug In	2	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	Incandescent	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	Not Sure	Ceiling light	Plug In		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	LED	Ceiling light	Plug In		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	Linear Fluorescent	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	Halogen	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway	CFL	Ceiling light	Plug In	3	Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Hallway						
1807575272	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Linear Fluorescent	Ceiling light	Built In	4	Moderate	
1807575272	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	
1807575272	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	2	Moderate	
1807575272	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Chandelier	Built In	6	Moderate	
1807999548	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	6	Dim	360 total
1807746078	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Table light		1	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1807746078	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1807746078	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Moderate	40..may be less
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Plug In	9	Bright	
1807999548	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	1	Moderate	not sure
1807999548	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In	1	Dim	
1807999548	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	1	Bright	Unkown
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	6	Bright	20
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Halogen	Ceiling light	Built In	1	Moderate	50
1808249327	Flat/ Apartment	Sharjah	After 2000	Property manager or other person	Dining room	Incandescent	Chandelier	Built In	16	Bright	40
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Halogen	Ceiling light	Plug In	2	Bright	50
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	6	Bright	20
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	2	Moderate	
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Not Sure	Ceiling light	Built In	2	Moderate	
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Table light	Plug In	1	Moderate	
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In		Moderate	
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In	2	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1808085874	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Plug In	4	Moderate	14
1808085874	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Plug In	4	Moderate	14
1808085874	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In	4	Moderate	14
1808089210	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Plug In	3	Bright	20
1808089210	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Chandelier	Plug In	3	Moderate	15
1808089210	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Chandelier		3	Moderate	20
1808115534	Flat/ Apartment	Dubai	After 2000	Member of household							
1808132797	Flat/ Apartment	Dubai	After 2000	Property manager or other person							
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person	Living Room	Incandescent	Table light	Plug In		Moderate	40
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person	Living Room	Linear Fluorescent	Ceiling light	Built In	4	Moderate	30
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person	Bedroom	Incandescent	Table light	Plug In	2	Dim	20
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	40
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	30
1808209469	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Plug In	1	Moderate	
1808209469	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	Not Sure	Ceiling light	Plug In	1	Moderate	
1808209469	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Chandelier	Plug In	1		

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1808209469	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom						
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Plug In	1	Moderate	14
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Living Room	LED	Chandelier	Plug In	1	Moderate	
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	1	Dim	
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light	Plug In	1	Bright	
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Bedroom	CFL	Ceiling light	Plug In	1	Bright	17
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Bedroom	Not Sure	Ceiling light	Plug In	1	Dim	14
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Bathroom	Incandescent	Ceiling light	Plug In	1	Dim	17
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Bathroom	LED	Ceiling light		1	Dim	
1808249327	Flat/ Apartment	Sharjah	After 2000	Property manager or other person	Bedroom	Incandescent	Chandelier	Built In	5	Bright	40
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	7	Moderate	80
1808249327	Flat/ Apartment	Sharjah	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Bright	40
1808264660	Flat/ Apartment	Dubai	After 2000	Member of household							
1808272718	Flat/ Apartment	Sharjah	After 2000	Property manager or other person							
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Incandescent	Table light	Plug In	1	Moderate	40
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Not Sure	Ceiling light	Plug In	1	Moderate	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	LED	Table light	Plug In	1	Dim	20
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	40
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Halogen	Table light	Plug In	1	Moderate	60
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In	1	Moderate	60
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Not Sure	Ceiling light	Plug In	1	Bright	60
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room	Not Sure	Ceiling light	Plug In	1	Bright	60
1808376992	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person							
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	6	Moderate	40
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Not Sure	Chandelier	Built In	5	Moderate	60
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	LED	Ceiling light	Built In	6	Moderate	60
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	10	Moderate	60
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Halogen	Ceiling light	Plug In	6	Bright	60
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Chandelier	Built In	4	Moderate	60
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Chandelier	Built In	6	Moderate	40
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	LED	Ceiling light	Built In	6	Moderate	80
1808847587	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Moderate	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1808847587	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Plug In	2	Dim	40
1808847587	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Plug In	2	Bright	60
1808847587	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	1	Moderate	60
1808869471	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1808869471	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	
1808869471	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	4	Moderate	
1808869471	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	6	Moderate	
1809127182	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household							
1809127275	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household							
1809135145	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	3	Bright	60
1809135145	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	6	Moderate	40
1809135145	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Halogen	Table light	Plug In	2	Moderate	20
1809135145	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	Linear Fluorescent	Ceiling light	Built In	4	Bright	
1809152473	Flat/ Apartment	Abu Dhabi	After 2000	Member of household							
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Incandescent	Ceiling light	Built In	3	Moderate	30
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Not Sure	Ceiling light	Built In	1	Moderate	30

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Not Sure	Chandelier	Plug In	1	Moderate	30
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	40
1805780267	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Chandelier				
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Linear Fluorescent	Ceiling light	Plug In	2	Moderate	40
1809434385	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Moderate	60
1809434385	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	60
1809434385	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room	Linear Fluorescent	Ceiling light	Built In	2	Moderate	60
1809519415	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Plug In	6	Dim	40
1809519415	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	LED	Ceiling light	Built In	6	Bright	60
1809519415	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	Incandescent	Ceiling light	Built In	2	Bright	40
1809519415	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bathroom	LED	Ceiling light	Built In	2	Moderate	40
1810357783	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	3	Moderate	40
1810357783	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	40
1810357783	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Incandescent	Ceiling light	Built In	2	Moderate	40
1810745669	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person							
1810788693	Flat/ Apartment	Abu Dhabi	After 2000	Member of household							

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	2	Bright	60
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	3	Bright	60
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent	Ceiling light		2		60
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Not Sure		Built In	2	Bright	60
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent			2		60
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	2		6
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	Incandescent	Ceiling light/ Chandelier/ Table Light	Built In/ Plug In	12	Moderate/ Bright	60
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	Not Sure	Ceiling light/ Chandelier/ Table light	Built In/ Plug In		Moderate	
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	LED	Table light			Bright	
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In		Bright	
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	Halogen	Chandelier/ Table light	Plug In		Moderate	
1797679448	villa	Sharjah	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light/ Chandelier	Built In/ Plug In		Moderate	80
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Plug In		Moderate	40-60
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Kitchen	Halogen	Chandelier			Dim	20-40
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Plug In		Bright	60-70
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In	2	Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Living Room	LED	Chandelier	Plug In		Dim	20-40
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Plug In		Bright	
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Linear Fluorescent	Chandelier	Built In		Moderate	40-60
1810860413	villa	Abu Dhabi	Before 1990	Member of household	Kitchen	Incandescent	Ceiling light			Bright	
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bathroom/ Hallway	Linear Fluorescent		Built In	16	Moderate	40
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bathroom/ Hallway	Not Sure	Ceiling light	Built In	13	Moderate	40
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bathroom/ Hallway	LED	Ceiling light				
1797679448	villa	Sharjah	Before 1990	Member of household	Living Room	Incandescent	Ceiling light/ Chandelier				
1797679448	villa	Sharjah	Before 1990	Member of household	Living Room	LED	Table light				
1797679448	villa	Sharjah	Before 1990	Member of household	Living Room	Linear Fluorescent	Ceiling light				
1810776393	villa	Abu Dhabi	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light	Plug In	2	Bright	19
1810776393	villa	Abu Dhabi	Before 1990	Member of household	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Plug In	4	Bright	21
1797679448	villa	Sharjah	Before 1990	Member of household	Living Room	CFL	Ceiling light				
1810776393	villa	Abu Dhabi	Before 1990	Member of household	Bathroom/ Dining Room/ Hallway	Linear Fluorescent	Ceiling light	Plug In	6	Bright	19
1797660866	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	1	Bright	80
1797660866	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light/ Table light	Built In/ Plug In	9	Moderate	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797660866	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Table light	Plug In	1	Moderate	60
1797660866	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light/ Table light	Built In/ Plug In	15	Moderate	60
1797669899	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	Halogen	Ceiling light	Built In	2	Bright	60
1797669899	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light/ Table light	Built In/ Plug In	4	Moderate	20/ 60
1797669899	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Ceiling light/ Table light	Built In/ Plug In	6	Moderate	20/ 60
1797678017	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	Incandescent	Ceiling light/ Table Light	Built In/ Plug In	2	Moderate/ Bright	40 / 60
1797678017	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light/ Table light	Built In/ Plug In	3	Moderate/ Bright	40 / 60
1797678017	Flat/ Apartment	Dubai	After 2000	Member of household	Hallway	Incandescent	Ceiling light	Built In	2	Moderate/ Bright	40 / 60
1797702253	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Living Room	Incandescent	Ceiling light	Built In	2	Moderate	75
1797702253	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Living Room	CFL	Table light	Plug In	2	Moderate	40
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent	Ceiling light	Built In	1	Bright	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Not Sure	Ceiling light	Built In	1	Moderate	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	LED	Ceiling light	Built In	1	Moderate	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Linear Fluorescent	Ceiling light	Built In	1&1	Dim/ Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Halogen	Ceiling light	Built In	2	Moderate	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Built In	1	Moderate	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	1	Moderate	
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Not Sure	Ceiling light	Built In	2	Moderate	
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Dining Room	Incandescent	Ceiling light	Built In	1	Moderate	60
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Dining Room	CFL	Ceiling light	Built In	2	Moderate	23
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent		Built In	1	Moderate	60
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL		Built In	2	Moderate	23
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent		Built In	1	Moderate	60
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL		Built In	2	Moderate	23
1797814573	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Bathroom	CFL	Ceiling light	Built In	1	Moderate	
1797814573	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Bathroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1797814573	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	1	Moderate	
1797814573	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	CFL	Ceiling light	Built In	1	Moderate	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen	Incandescent	Ceiling light	Built In	1	Dim	60
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen	Not Sure	Ceiling light	Built In	4	Moderate	60
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen	Halogen	Table light	Plug In	1	Dim	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen	CFL	Chandelier	Built In	2	Moderate	60
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	Incandescent	Ceiling light	Built In		Dim	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	LED	Chandelier	Built In		Dim	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In		Dim	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	Halogen	Ceiling light	Plug In		Dim	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light			Moderate	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room	Not Sure	Ceiling light	Built In		Moderate	
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household	Bathroom	Incandescent	Ceiling light	Built In	1		
1797917052	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Built In	12	Bright	
1797917052	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Not Sure	Ceiling light	Built In		Bright	
1797917052	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	1	Bright	75
1797917052	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Hallway	CFL	Ceiling light	Built In	4	Bright	40

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	CFL	Table light	Plug In	4	Moderate	100
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	Not Sure	Ceiling light/ Chandelier/ Table light	Built In/ Plug In	15	Moderate/ Bright	150W
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	Linear Fluorescent	Ceiling light	Built In/ Plug In	9	Bright	100
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom						
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room						
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Incandescent		Built In			
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Bright	
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light/ Table light	Built In/ Plug In	6 BI, 2 PI lamps (40W PI)	Dim	
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room/ Dining Room	Incandescent	Chandelier/ Table light	Built In/ Plug In	6 BI, 3 PI lamps (40W PI)	Moderate	
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room/ Dining Room	CFL	Ceiling light	Built In	2	Bright	
1798090229	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Bright	60
1798090229	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light/ Table light	Plug In	3	Moderate	40
1798090229	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Table light	Plug In	2	Moderate	40
1798090229	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Ceiling light/ Chandelier	Plug In	8	Bright	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798304100	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Dining Room	Incandescent	Ceiling light	Built In	6	Moderate	40
1798304100	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Dining Room	Linear Fluorescent	Ceiling light	Built In	8	Dim	40
1798304100	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Dining Room	CFL	Ceiling light	Built In	6	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Bathroom	CFL	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	Incandescent	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	LED	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	Halogen	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room	Not Sure	Ceiling light	Built In	4	Moderate	40
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	4	Moderate	40
1798370354	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen/ Living Room/ Dining Room	Incandescent	Ceiling light	Built In	8	Moderate	40
1798370354	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen/ Living Room/ Dining Room	CFL	Table light	Plug In	5	Moderate	40
1798370354	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	2	Moderate	40
1798370354	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bathroom	Incandescent	Ceiling light	Built In	4	Bright	60
1798541247	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom	Not Sure	Ceiling light	Built In	2	Moderate	40

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1798541247	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	40
1798541247	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	2	Moderate	15
1800314077	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom/ Living room/ Bathroom	CFL	Ceiling light	Built In	2	Bright	40
1800314077	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL		Built In	3	Bright	
1800314077	Flat/ Apartment	Dubai	After 2000	Member of household	Bathroom	CFL		Built In	1	Moderate	
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom	Incandescent		Plug In	2	Moderate	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom	CFL	Ceiling light	Built In	1	Moderate	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent			1	Dim	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Not Sure	Ceiling light	Built In	1	Moderate	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	LED				Dim	
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Linear Fluorescent	Table light	Plug In	0	Dim	23
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Halogen	CFL	Plug In		Dim	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Built In	1	Dim	35
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom	Not Sure	Ceiling light	Built In	1	Moderate	35

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1800409941	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Plug In	3	Moderate	25
1800409941	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Linear Fluorescent	Ceiling light	Built In	2	Moderate	3
1800409941	Flat/ Apartment	Sharjah	After 2000	Member of household	Kitchen						
1800409941	Flat/ Apartment	Sharjah	After 2000	Member of household	Bedroom						
1800990417	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	CFL	Ceiling light	Plug In	6	Moderate	35
1802004096	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent	Ceiling light/ Chandelier/ Table Light	Built In	2	Moderate	
1802004096	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Chandelier	Built In	4	Moderate	
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	2	Moderate	
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Bedroom	CFL	Ceiling light	Built In	5	Moderate	40
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Living Room/ Bathroom/ Hallway	Incandescent	Ceiling light	Built In	2	Moderate	40
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Living Room/ Bathroom/ Hallway	Linear Fluorescent	Ceiling light	Built In	3	Moderate	
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Living Room/ Bathroom/ Hallway	CFL	Ceiling light	Built In	2	Moderate	40
1802380452	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	CFL	Ceiling light/ Chandelier	Plug In	6	Moderate	16
1802380452	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Dining Room	CFL	Ceiling light	Built In	6		18

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1802380452	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Plug In	6	Moderate	18
1803804812	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen/ Bedroom	CFL	Ceiling light/ Chandelier	Built In	6	Moderate	8
1803804812	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Halogen	Ceiling light	Built In	1		
1803804812	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	CFL	Chandelier	Built In	6	Moderate	8 each
1803841912	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	3	Moderate	60
1803841912	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Table light	Plug In	1	Moderate	12
1803841912	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	2	Bright	11
1803841912	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light/ Chandelier	Built In/ Plug In	5	Moderate	60
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Built In	8	Moderate/ Bright	60
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Not Sure	Ceiling light	Built In	11	Moderate/ Bright	60
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Halogen	Ceiling light	Built In	3	Bright	60
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	CFL	Ceiling light	Built In	1	Bright	100
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Halogen	Ceiling light	Built In	1	Moderate	60
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	2	Bright	100
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Incandescent	Ceiling light/ Chandelier	Built In	4	Bright	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In	2	Moderate	40
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light	Built In	2	Moderate	12
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Bedroom	Incandescent	Ceiling light	Built In	3	Moderate	60
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Bedroom	Linear Fluorescent	Ceiling light	Built In	2	Moderate	40
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	Incandescent	Ceiling light	Built In	4	Moderate	60
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person	Living Room	CFL	Ceiling light	Built In	4	Moderate	12
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent	Ceiling light	Built In	8	Moderate	25
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Halogen	Ceiling light	Built In	10	Moderate	12
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Ceiling light	Built In	6	Moderate	40
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	14	Moderate	25
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	8	Moderate	40
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	Incandescent	Ceiling light	Built In	5	Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	Not Sure	Ceiling light	Built In		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	LED	Ceiling light	Plug In		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	Linear Fluorescent	Table light	Built In		Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	Halogen	Ceiling light	Plug In		Dim	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room/ Dining Room/ Hallway	CFL	Chandelier	Plug In		Moderate	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent	Ceiling light	Plug In		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	LED	Chandelier	Plug In		Moderate	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Linear Fluorescent	Ceiling light	Built In		Dim	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Halogen	Table light	Built In		Moderate	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	CFL	Table light	Plug In		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Not Sure	Chandelier	Built In		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen/ Bedroom/ Bathroom/ Dining Room	Incandescent	Table light				
1806237274	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	8	Moderate	
1806237274	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Living Room	Incandescent	Chandelier/ Table light	Built In/ Plug In	6+4 lamps (60+40W each)	Moderate	
1806237274	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Bedroom	Incandescent	Chandelier/ Table light	Built In/ Plug In	3+1 lamps (60+40W each)	Moderate	
1806478181	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Hallway	CFL	Ceiling light	Built In	5	Bright	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1806478181	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	2	Moderate	60
1806478181	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	5	Bright	60
1806576199	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	2	Moderate	19
1806576199	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Bedroom	Linear Fluorescent	Ceiling light	Built In	6	Moderate	
1806576199	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	Living Room/ Bathroom	Linear Fluorescent	Ceiling light	Built In	8	Moderate	
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room	Incandescent	Ceiling light/ Chandelier	Built In	2	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room	LED	Ceiling light	Built In	2	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room	Linear Fluorescent	Ceiling light	Built In	1	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room	CFL	Ceiling light/ Chandelier	Built In	2	Moderate	25
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent	Ceiling light	Built In	3	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	LED	Ceiling light	Built In	2	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Linear Fluorescent	Ceiling light	Built In	1	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	CFL	Ceiling light/ Chandelier	Built In	2	Moderate	25
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	Incandescent	Ceiling light	Built In	1	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	LED	Ceiling light	Built In	2	Moderate	25

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	Linear Fluorescent	Ceiling light	Built In	1	Moderate	60
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	2	Moderate	60
1807305878	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Moderate	18
1807305878	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Incandescent	Ceiling light/ Table light	Built In/ Plug In	5	Moderate	40-60
1807305878	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Bedroom	Halogen	Ceiling light	Built In	6	Moderate	35
1807305878	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light/ Table light	Built In/ Plug In	6	Moderate	40-60
1807309284	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bedroom/ Living room/ Dining Room	Incandescent	Ceiling light	Plug In	2	Dim	20
1807309284	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Living Room	Incandescent	Ceiling light	Plug In	2	Moderate	40
1807309284	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Bathroom	Incandescent	Ceiling light	Plug In	2	Moderate	40
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In/ Plug In	3	Moderate	60
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household	Living Room	CFL	Ceiling light/ Chandelier/ Table light	Built In/ Plug In	8	Moderate	9
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household	Kitchen	CFL	Ceiling light	Built In	2	Moderate	9
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	Incandescent	Chandelier	Built In	3	Moderate	60
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household	Bedroom	CFL	Chandelier	Built In	4	Moderate	9
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Kitchen/ Bedroom/ Bathroom	CFL	Ceiling light	Built In	2	Bright	
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Kitchen/ Bedroom/ Bathroom	Not Sure				Bright	

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Bathroom	CFL	Ceiling light	Built In		Bright	
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Bathroom	Not Sure				Bright	
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Bedroom	CFL	Ceiling light	Built In		Bright	
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household	Bedroom	Not Sure				Bright	
1809116821	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household	Kitchen/ Bedroom/ Living Room/ Bathroom/ Dining Room/ Hallway	Incandescent	Ceiling light	Built In	2	Bright	
1809762654	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	8	Bright	15*8
1809762654	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	Incandescent	Ceiling light/ Table light	Built In/ Plug In	3 lamps (40, 40, 100W)	Dim/ Moderate	
1809762654	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	Incandescent	Chandelier	Built In	6	Bright	6*75
1809762654	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room	CFL	Ceiling light	Built In	2	Moderate	24, 24
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Incandescent	Chandelier	Plug In	15	Bright	60
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Not Sure	Chandelier	Built In	6	Moderate	60
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Linear Fluorescent	Ceiling light	Built In	6	Moderate	40
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	Halogen	Table light	Plug In	1	Dim	30
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen/ Bedroom/ Living Room	CFL	Ceiling light	Built In	5	Moderate	40
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen	CFL	Ceiling light	Built In	6	Moderate	60
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Kitchen	Not Sure	Ceiling light	Built In	6	Moderate	60

Summary of Voluntary Residential Lighting Survey – Interior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Type of Room	Lamp Technology	Type of Luminaire	Mounting	No. of Lamps	Brightness	Wattage
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person	Bedroom	Not Sure	Chandelier	Built In	1	Moderate	40
1810901676	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Kitchen	Linear Fluorescent	Ceiling light	Built In	4	Moderate	19
1810901676	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Bedroom	CFL	Ceiling light	Built In	1	Moderate	19
1810901676	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Living Room/ Bathroom	CFL	Ceiling light/ Table light	Built In	3	Moderate	19
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	corridoor	Incandescent			3	Moderate	60
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	hallway	Halogen			4	Moderate	75
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	rooms	CFL			5	Moderate	60
1804387321	villa	Abu Dhabi	After 2000	Property manager or other person	kitchen and bathrooms	Linear fluorescent			10	Moderate	60
1806503566	villa	Abu Dhabi	Before 1990	Member of household	Corridor	Linear fluorescent			1	Moderate	
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	living room	Incandescent			4	Moderate	40 to 60
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	living room	Halogen			1	Moderate	31 to 50
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	bed room	CFL			1	Moderate	12 to 19
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	bath room	Linear fluorescent			1	Moderate	16 to 21
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	living room	LED			1	Moderate	16 to 21
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Ceiling	CFL			2	Bright	
1797810913	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household	Dining Hall	Linear fluorescent			4	Bright	

Summary of Voluntary Residential Lighting Survey – Exterior Lighting

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1794340345	villa	Abu Dhabi	Before 1990	Member of household					
1794440681	villa	Abu Dhabi	Between 1990 and 2000	Property manager or other person					
1797715078	villa	Abu Dhabi	After 2000	Property manager or other person					
1797750972	villa	Dubai	After 2000	Member of household					
1797772800	villa	Dubai	Between 1990 and 2000	Member of household					
1797779850	villa	Abu Dhabi	After 2000	Property manager or other person	Outside Main Door	CFL	1	Bright	
1797943995	villa	Abu Dhabi	Between 1990 and 2000	Member of household	2	Linear fluorescent	2	Moderate	
1797948965	villa	Abu Dhabi	After 2000	Member of household					
1797949414	villa	Abu Dhabi	After 2000	Property manager or other person					
1797949827	villa	Abu Dhabi	After 2000	Property manager or other person					
1797966696	villa	Abu Dhabi	After 2000	Member of household					
1797967091	villa	Dubai	After 2000	Member of household					
1797987374	villa	Dubai	Between 1990 and 2000	Member of household					
1797996992	villa	Dubai	Between 1990 and 2000	Member of household					
1798349616	villa	Dubai	After 2000	Member of household					
1798366458	villa	Dubai	After 2000	Property manager or other person					
1798408213	villa	Abu Dhabi	After 2000	Property manager or other person	front and back yard and front porch	CFL	19	Moderate	
1798615159	villa	Dubai	Between 1990 and 2000	Member of household	luminaoire	Not Sure			
1799369514	villa	Dubai	After 2000	Member of household	all rooms and garden	CFL	100	Moderate	1200
1799369514	villa	Dubai	After 2000	Member of household	all rooms and garden	LED	100	Moderate	1000
1799461299	villa	Dubai	Between 1990 and 2000	Member of household	Lawn, Garage	Incandescent	10	Dim	
1799461299	villa	Dubai	Between 1990 and 2000	Member of household	Lawn	Linear fluorescent	1	Bright	

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1799528681	villa	Sharjah	After 2000	Property manager or other person					
1800714352	villa	Sharjah	Between 1990 and 2000	Member of household					
1802727392	villa	Dubai	After 2000	Property manager or other person					
1803992862	villa	Abu Dhabi	Between 1990 and 2000	Member of household					
1805625734	villa	Dubai	After 2000	Member of household					
1807322836	villa	Abu Dhabi	Between 1990 and 2000	Member of household	out side	Not Sure	1	Moderate	40 to 60
1807529325	villa	Dubai	Before 1990	Member of household					
1808039777	villa	Sharjah	After 2000	Property manager or other person					
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person		CFL		Moderate	70
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person		Linear fluorescent		Moderate	60
1808081840	villa	Abu Dhabi	After 2000	Property manager or other person		Not Sure	2	Moderate	
1808308432	villa	Abu Dhabi	After 2000	Property manager or other person	entrance	CFL	3	Moderate	?
1810784397	villa	Abu Dhabi	Before 1990	Member of household	fence	CFL	15	Bright	<19
1810811269	villa	Abu Dhabi	Before 1990	Member of household					
1810860413	villa	Abu Dhabi	Before 1990	Member of household					
1803818687	Studio	Abu Dhabi		Property manager or other person					
1797651042	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1797652635	Flat/ Apartment	Dubai	After 2000	Member of household					
1797663026	Flat/ Apartment	Dubai	After 2000	Member of household					
1797665222	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person					
1797668904	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1797670661	Flat/ Apartment	Dubai	After 2000	Property manager or other person	Balcony	Incandescent	2	Moderate	30

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1797680572	Flat/ Apartment	Dubai	After 2000	Member of household					
1797712349	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1797759409	Flat/ Apartment	Sharjah	After 2000	Member of household					
1797816515	Flat/ Apartment	Sharjah	After 2000	Property manager or other person					
1797881619	Flat/ Apartment	Dubai	After 2000	Member of household					
1797927144	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1797965756	Flat/ Apartment	Sharjah	After 2000	Member of household					
1797981107	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1797989469	Flat/ Apartment	Dubai	After 2000	Member of household					
1797990962	Flat/ Apartment	Dubai	Before 1990	Member of household					
1798010396	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1798044271	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person					
1798046433	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1798050480	Flat/ Apartment	Dubai	After 2000	Member of household					
1798310172	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1798326391	Flat/ Apartment	Dubai	After 2000	Member of household					
1798336898	Flat/ Apartment	Dubai	After 2000	Property manager or other person					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1798337129	Flat/ Apartment	Sharjah	After 2000	Member of household					
1798339462	Flat/ Apartment	Dubai	After 2000	Member of household					
1798343694	Flat/ Apartment	Dubai	After 2000	Member of household					
1798351724	Flat/ Apartment	Ajman	After 2000	Member of household					
1798362552	Flat/ Apartment	Dubai	After 2000	Member of household					
1798364376	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1798366689	Flat/ Apartment	Dubai	After 2000	Member of household					
1798374805	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					
1798383030	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1798480379	Flat/ Apartment	Dubai	After 2000	Member of household					
1798480559	Flat/ Apartment	Dubai	After 2000	Member of household					
1798536298	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1798597279	Flat/ Apartment	Sharjah	After 2000	Member of household					
1798606251	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1798633086	Flat/ Apartment	Dubai	After 2000	Member of household					
1798949859	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1799057904	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1799155474	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					
1799600630	Flat/ Apartment	Sharjah	After 2000	Member of household					
1799950389	Flat/ Apartment	Dubai	After 2000	Member of household					
1800108762	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1800190160	Flat/ Apartment	Sharjah	After 2000	Member of household					
1800221039	Flat/ Apartment	Sharjah	After 2000	Member of household					
1800274870	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person					
1800283944	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person					
1800287392	Flat/ Apartment	Sharjah	After 2000	Member of household					
1800332905	Flat/ Apartment	Dubai	After 2000	Member of household					
1800367376	Flat/ Apartment	Fujairah	After 2000	Member of household		CFL		Dim	
1800425699	Flat/ Apartment	Sharjah	After 2000	Property manager or other person					
1801125718	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1801266152	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person					
1801542626	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1802008387	Flat/ Apartment	Dubai	After 2000	Member of household					
1802012579	Flat/ Apartment	Dubai	After 2000	Property manager or other person					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1802035119	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1802075119	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1802095999	Flat/ Apartment	Dubai	After 2000	Member of household					
1802107185	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1802121169	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1802413548	Flat/ Apartment	Dubai	After 2000	Member of household					
1802624378	Flat/ Apartment	Dubai	After 2000	Member of household					
1803061121	Flat/ Apartment	Dubai	After 2000	Member of household					
1803338902	Flat/ Apartment	Sharjah	After 2000	Member of household					
1803776244	Flat/ Apartment	Sharjah	After 2000	Member of household					
1803781554	Flat/ Apartment	Dubai	After 2000	Member of household					
1803795077	Flat/ Apartment	Umm al Quwain	Before 1990	Property manager or other person					
1803795446	Flat/ Apartment	Dubai	Before 1990	Member of household					
1803829348	Flat/ Apartment	Ajman	After 2000	Member of household					
1803831117	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1803831789	Flat/ Apartment	Ras Al Khaimah	Between 1990 and 2000	Property manager or other person					
1803855995	Flat/ Apartment	Dubai	Before 1990	Member of household		Not Sure	1	Moderate	120

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1803879890	Flat/ Apartment	Sharjah	After 2000	Member of household					
1803885727	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1803965979	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person	outside	CFL	1	Bright	40
1804245792	Flat/ Apartment	Dubai	Before 1990	Member of household					
1804435616	Flat/ Apartment	Dubai	After 2000	Member of household					
1804468287	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person					
1804652614	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person					
1804805528	Flat/ Apartment	Dubai	After 2000	Property manager or other person	1	Incandescent	2	Moderate	2
1805780267	Flat/ Apartment	Dubai	After 2000	Member of household					
1805854096	Flat/ Apartment	Dubai	After 2000	Member of household					
1805891056	Flat/ Apartment	Dubai	After 2000	Member of household					
1805927117	Flat/ Apartment	Dubai	After 2000	Member of household					
1806616220	Flat/ Apartment	Dubai	After 2000	Member of household					
1806642517	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1807262962	Flat/ Apartment	Dubai	After 2000	Member of household					
1807326425	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		Incandescent		Moderate	

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		CFL		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		Halogen		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		Linear fluorescent		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		LED		Moderate	
1807559622	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person		Not Sure		Moderate	
1807575272	Flat/ Apartment	Dubai	After 2000	Property manager or other person	balcony	Incandescent	1	Moderate	60
1807746078	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1807999548	Flat/ Apartment	Dubai	After 2000	Member of household					
1808029575	Flat/ Apartment	Dubai	After 2000	Member of household					
1808082372	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1808085874	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1808089210	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1808115534	Flat/ Apartment	Dubai	After 2000	Member of household					
1808132797	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1808186727	Flat/ Apartment	Dubai	Before 1990	Property manager or other person					
1808209469	Flat/ Apartment	Sharjah	After 2000	Member of household					
1808215926	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household		Not Sure	1	Dim	

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1808249327	Flat/ Apartment	Sharjah	After 2000	Property manager or other person					
1808264660	Flat/ Apartment	Dubai	After 2000	Member of household					
1808272718	Flat/ Apartment	Sharjah	After 2000	Property manager or other person					
1808372106	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person					
1808376992	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person					
1808394849	Flat/ Apartment	Dubai	After 2000	Member of household					
1808847587	Flat/ Apartment	Dubai	After 2000	Member of household					
1808869471	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1809127182	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1809127275	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1809135145	Flat/ Apartment	Dubai	After 2000	Member of household					
1809152473	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					
1809303781	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1809434385	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person					
1809519415	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1810357783	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person					
1810745669	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Property manager or other person					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1810788693	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					
1810813305	Flat/ Apartment	Abu Dhabi	After 2000	Member of household		Not Sure	2	Bright	60
1797679448	villa	Sharjah	Before 1990	Member of household					
1797719351	villa	Dubai	Between 1990 and 2000	Member of household	4	Incandescent	4	Bright	
1798367984	villa	Dubai	Between 1990 and 2000	Member of household	5	Incandescent		Dim	25
1810776393	villa	Abu Dhabi	Before 1990	Member of household	vence	Linear Fluorescent	10	Bright	19
1797660866	Flat/ Apartment	Dubai	After 2000	Member of household					
1797669899	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1797678017	Flat/ Apartment	Dubai	After 2000	Member of household					
1797702253	Flat/ Apartment	Dubai	After 2000	Member of household					
1797711949	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1797810154	Flat/ Apartment	Sharjah	After 2000	Member of household					
1797814573	Flat/ Apartment	Dubai	After 2000	Member of household					
1797899748	Flat/ Apartment	Ajman	Between 1990 and 2000	Member of household					
1797917052	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1797934349	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1798013166	Flat/ Apartment	Dubai	After 2000	Member of household					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1798090229	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1798304100	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					
1798332375	Flat/ Apartment	Sharjah	After 2000	Member of household					
1798370354	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person					
1798541247	Flat/ Apartment	Sharjah	Between 1990 and 2000	Member of household					
1800314077	Flat/ Apartment	Dubai	After 2000	Member of household					
1800335417	Flat/ Apartment	Sharjah	After 2000	Member of household					
1800409941	Flat/ Apartment	Sharjah	After 2000	Member of household					
1800990417	Flat/ Apartment	Dubai	After 2000	Member of household					
1802004096	Flat/ Apartment	Dubai	After 2000	Member of household					
1802078562	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household					
1802380452	Flat/ Apartment	Dubai	After 2000	Member of household		CFL		Moderate	
1803804812	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1803841912	Flat/ Apartment	Dubai	After 2000	Member of household					
1804056993	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1805796028	Flat/ Apartment	Dubai	Between 1990 and 2000	Property manager or other person					
1805872771	Flat/ Apartment	Dubai	After 2000	Member of household					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		Incandescent		Moderate	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		CFL		Moderate	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		Halogen		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		Linear Fluorescent		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		LED		Bright	
1805956631	Flat/ Apartment	Dubai	After 2000	Property manager or other person		Not Sure		Bright	
1806237274	Flat/ Apartment	Dubai	After 2000	Property manager or other person					
1806478181	Flat/ Apartment	Dubai	After 2000	Member of household					
1806576199	Flat/ Apartment	Abu Dhabi	After 2000	Property manager or other person					
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Balcony	Incandescent	2	Moderate	100
1807294610	Flat/ Apartment	Abu Dhabi	After 2000	Member of household	Wall	CFL	4	Moderate	20
1807305878	Flat/ Apartment	Dubai	Between 1990 and 2000	Member of household					
1807309284	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1807483231	Flat/ Apartment	Dubai	After 2000	Member of household					
1807696900	Flat/ Apartment	Abu Dhabi	Before 1990	Member of household					
1809116821	Flat/ Apartment	Abu Dhabi	Between 1990 and 2000	Member of household					
1809762654	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					

Summary of Voluntary Residential Lighting Survey – Exterior Lighting (continued)

Respondent ID	Housing Unit Type	Emirate	Year Constructed	Who is Responsible	Location	Lamp Technology	No. of Lamps	Brightness	Wattage
1810149812	Flat/ Apartment	Sharjah	Between 1990 and 2000	Property manager or other person					
1810901676	Flat/ Apartment	Abu Dhabi	After 2000	Member of household					

Appendix VI

Results of Lighting Products Market Survey

Store	Type	Manufacturer	Rating		Price (AED)	Price (AED)	Comments
			Watts	Lumens			
Lulu	Compact Fluorescent	Panasonic	5		10.00	10.00 ea	
Nasa Electrical	Compact Fluorescent	Tungsram	7		6.00	6.00 ea	
Bahri & Mazroei	Compact Fluorescent	Tungsram	7		6.00	6.00 ea	
Granite Super Market	Compact Fluorescent	Galux	7		8.00	8.00 ea	
Lulu	Compact Fluorescent	Philips	8		11.50	11.50 ea	
Lulu	Compact Fluorescent	Philips	8		12.50	12.50 ea	
Abu Dhabi Cooperative	Compact Fluorescent	Philips	8		15.00	15.00 ea	
Lulu	Compact Fluorescent	GE	8	460	15.50	15.50 ea	
Abu Dhabi Cooperative	Compact Fluorescent	Sunlight	8		6.50	19.50/3	Pack of 3
Abu Dhabi Cooperative	Compact Fluorescent	GE	9	600	7.50	7.50 ea	
Lulu	Compact Fluorescent	Panasonic	11		10.00	10.00 ea	
Bahri & Mazroei	Compact Fluorescent	GE	11	500	10.00	10.00 ea	
Granite Super Market	Compact Fluorescent	Philips	11		13.50	13.50 ea	
Lulu	Compact Fluorescent	GE	13		12.00	12.00 ea	
Carrefour	Compact Fluorescent	Osram	13	855	15.90	15.90 ea	
Bahri & Mazroei	Compact Fluorescent	GE	14		12.00	12.00 ea	Special in-ceiling fixture
Lulu	Compact Fluorescent	Philips	15		14.00	14.00 ea	
Granite Super Market	Compact Fluorescent	Smartlite	15		14.50	14.50 ea	
Lulu	Compact Fluorescent	Philips	17		17.00	17.00 ea	
Bahri & Mazroei	Compact Fluorescent	GE	18		10.00	10.00 ea	BIAX - 4 pin
Lulu	Compact Fluorescent	Philips	18		14.00	14.00 ea	
Nasa Electrical	Compact Fluorescent	Osram	18		9.00	9.00 ea	
Bahri & Mazroei	Compact Fluorescent	GE	20	1150	12.00	12.00 ea	
Abu Dhabi Cooperative	Compact Fluorescent	GE	20	1152	16.00	16.00 ea	
Lulu	Compact Fluorescent	GE	20	1152	16.50	16.50 ea	
Lulu	Compact Fluorescent	Philips	20		17.00	17.00 ea	
Lulu	Compact Fluorescent	GE	20	1152	10.00	20.00/2	Long tube- Pack of 2
Abu Dhabi Cooperative	Compact Fluorescent	GE	20	1152	21.00	21.00 ea	
Lulu	Compact Fluorescent	GE	20	1152	10.50	21.00/2	Compact-Pack of 2
Nasa Electrical	Compact Fluorescent	Ouqi	20		6.50	6.50 ea	

Store	Type	Manufacturer	Rating		Price (AED)	Price (AED)	Comments
			Watts	Lumens			
Granite Super Market	Compact Fluorescent	Oreva	23		10.00	10.00 ea	
Carrefour	Compact Fluorescent	Osram	23		10.75	10.75 ea	
Carrefour	Compact Fluorescent	Suntech	23		11.00	11.00 ea	
Carrefour	Compact Fluorescent	Philips	23		16.90	16.90 ea	
Abu Dhabi Cooperative	Compact Fluorescent	GE	23	1297	22.00	22.00 ea	
Carrefour	Compact Fluorescent	GE	23	1242	22.00	22.00 ea	
Abu Dhabi Cooperative	Compact Fluorescent	Philips	23		11.50	23.00/2	Pack of 2
Abu Dhabi Cooperative	Compact Fluorescent	GE	23	1297	26.00	26.00 ea	
Lulu	Compact Fluorescent	GE	23	1297	26.50	26.50 ea	
Granite Super Market	Compact Fluorescent	Philips	23		7.50	7.50 ea	
Carrefour	Compact Fluorescent	Suntech	25		12.50	12.50 ea	
Carrefour	Compact Fluorescent	First 1	25		5.50	5.50 ea	
Bahri & Mazroei	Compact Fluorescent	Ouqi	26		7.00	7	
Granite Super Market	Compact Fluorescent	APE Apple	26		12.00	12.00 ea	
Nasa Electrical	Compact Fluorescent	Ouqi	26		7.00	7.00 ea	
Carrefour	Fluorescent Tube	Osram	18		2.50	2.50 ea	24 inch
Carrefour	Fluorescent Tube	GE	18		3.90	3.90 ea	24 inch
Lulu	Fluorescent Tube	Philips	36		5.00	5.00 ea	48 inch tube
Abu Dhabi Cooperative	Halogen	Philips	11		18.00	18.00 ea	
Nasa Electrical	Halogen	Osram	15		3.00	3.00 ea	
Nasa Electrical	Halogen	Osram	20		4.00	4.00 ea	
Abu Dhabi Cooperative	Halogen	Philips	23		17.00	17.00 ea	
Carrefour	Halogen	Osram	50		2.50	2.50 ea	Spot reflector
Nasa Electrical	Halogen	Osram	50		3.00	3.00 ea	Spot halogen
Carrefour	Halogen	GE	50		4.90	4.90 ea	Spot reflector
Bahri & Mazroei	Halogen	GE	50		5.00	5.00 ea	
Lulu	Halogen	GE	50		6.25	6.25 ea	Decorative reflector spot
Abu Dhabi Cooperative	Incandescent	GE	15		1.75	1.75 ea	Decorator bulb - color
Lulu	Incandescent	GE	40		1.25	1.25 ea	Pack of 10
Abu Dhabi Cooperative	Incandescent	Philips	40		1.29	1.29 ea	

Store	Type	Manufacturer	Rating		Price (AED)	Price (AED)	Comments
			Watts	Lumens			
Carrefour	Incandescent	GE	40		1.90	1.90 ea	Decorator ball style decorator bulb
Carrefour	Incandescent	GE	40		2.50	2.50 ea	Oval chandelier bulb
Lulu	Incandescent	GE	40		2.75	2.75 ea	Spot light
Abu Dhabi Cooperative	Incandescent	GE	40		4.00	4.00 ea	
Carrefour	Incandescent	GE	40		5.00	5.00 ea	Incandescent reflector spot
Carrefour	Incandescent	Osram	60		0.95	0.95 ea	
Carrefour	Incandescent	GE	60		1.20	1.20 ea	
Nasa Electrical	Incandescent	Osram	60		1.25	1.25 ea	Candle bulb
Carrefour	Incandescent	Osram	60		1.25	1.25 ea	Oval chandelier bulb
Carrefour	Incandescent	Philips	60		1.25	1.25 ea	
Carrefour	Incandescent	J&C	60		1.25	1.25 ea	
Abu Dhabi Cooperative	Incandescent	GE	60	660	1.75	1.75 ea	Decorator bulb - small
Bahri & Mazroei	Incandescent	GE	60		2.00	2.00 ea	
Lulu	Incandescent	GE	75		1.25	1.25 ea	
Lulu	Incandescent	GE	75		4.00	4.00 ea	Decorator bulb
Carrefour	Incandescent	Osram	100		0.95	0.95 ea	
Carrefour	Incandescent	Sylvania	100		1.15	1.15 ea	
Carrefour	Incandescent	GE	100		1.20	1.20 ea	
Abu Dhabi Cooperative	Incandescent	GE	100		1.25	1.25 ea	GE Classic Soft light
Carrefour	Incandescent	GE	100		1.19	11.90/10	Pack of 10
Granite Super Market	Incandescent	Philips	100	1330	1.38	13.75/10	Pack of 10
Carrefour	Incandescent	GE	100		3.90	3.90 ea	Incandescent reflector spot
Abu Dhabi Cooperative	Incandescent	GE	100		4.00	4.00 ea	Reflector bulb
Abu Dhabi Cooperative	Incandescent	GE	150		5.00	5.00 ea	
Lulu	Incandescent	GE	150		5.00	5.00 ea	
Abu Dhabi Cooperative	Incandescent	GE	200		6.00	6.00ea	
Lulu	LED	Philips	1		40.00	40.00 ea	Decorative light
Carrefour	LED	J&C	2		32.90	32.90 ea	
Carrefour	LED	J&C	2.5	200	39.00	39.00 ea	

Store	Type	Manufacturer	Rating		Price (AED)	Price (AED)	Comments
			Watts	Lumens			
Carrefour	LED	Sylvania	6	250	125.00	125	
Lulu	LED	Sylvania	6	250	125.00	125	
Bahri & Mazroei	LED	LG	7.5	450	95.00	95.00 ea	
Carrefour	LED	Osram	15		62.00	62.00 ea	
Lulu	LED	Philips	25	250	85.00	85.00 ea	
Lulu	LED	Philips	32	350	159.00	159.00 ea	
Bahri & Mazroei	Metal Halide	GE	70		70.00	70.00 ea	Metal Halide - 2 pin

TECHNICAL MEMORANDUM 2

ASSESSMENT OF TECHNICAL, ECONOMIC, AND ACHIEVABLE POTENTIAL

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LIST OF ABBREVIATIONS

ADWEA ... Abu Dhabi Water and Electricity Authority
AGEDI ... Abu Dhabi Global Environmental Data Initiative
CFL ... Compact fluorescent lamp
CO_2 ... Carbon dioxide
CO_2eq ... CO_2 equivalents
DEWA ... Dubai Electricity and Water Authority
DSM ... Demand-side management
EAA ... Executive Affairs Authority
EAD ... Environment Agency – AbuDhabi
EEL ... Energy-efficient lighting
EF ... Ecological Footprint
EFI ... Ecological Footprint Initiative
ESMA ... Emirates Authority forStandardization and Metrology
EWS-WWF ... Emirates Wildlife Society, in association with the World Wide Fund for Nature
FEWA ... Federal Electricity and Water Authority
GFN ... Global Footprint Network
GHG ... Greenhouse gas
LED ... Light-emitting diode
MC ... Marginal Cost
MELA ... Middle East Lighting Association
MEPS ... Minimum Efficiency Performance Standard
MOEW ... Ministry of Environment and Water
SEWA ... Sharjah Electricity and Water Authority
UAE ... United Arab Emirates
USAID ... U.S. Agency for International Development

1. Introduction

This report presents the technical, economic, and achievable potential assessment for the development of residential lighting standards for the United Arab Emirates (UAE). Annual impacts in terms of energy savings, financial benefits to households, and subsidy reductions for governments are estimated for the currently existing stock of residential buildings and lighting characteristics.

The technical, economic, and achievable potential assessment is one component of an overall study, Development of Lighting Standards for the United Arab Emirates, to establish the basis and recommendations for developing residential lighting standards for the UAE. **Section 1.1** explains the background and purpose of this study and includes a description of the tasks to be conducted. The remainder of **Section 1** describes all the components of the study and the organization of this specific report.

1.1 Background and Purpose

The UAE has one of the highest per-capita carbon footprints in the world and a growing gap between demand and supply of energy (World Wildlife Fund, 2012). In combination with being a rapidly developing country and growing population, the UAE is facing an urgent need to evaluate and establish standards for reducing energy consumption in all sectors, including the residential sector, in a manner that is protective of the environment and of the country's economic and social well-being.

In 2007, the UAE's Ecological Footprint Initiative (EFI) was established through a partnership with the Ministry of Environment and Water (MoEW); the Environment Agency – Abu Dhabi (EAD)[1]; the Emirates Wildlife Society, in association with the World Wide Fund for Nature (EWS-WWF); the Global Footprint Network (GFN); and more recently, the Emirates Authority for Standardization and Metrology (ESMA) to manage its Ecological Footprint (EF) through research, policy, and practice. The knowledge gained from the EFI has benefited the country by creating opportunities for UAE government leaders and residents to move towards sustainable development.

The EFI continues to tackle the country's EF and began a new phase of work in 2012. Included in this scope of work is research to support ESMA in the development of an energy-efficient lighting standard and labeling system for the UAE's residential sector.

The objective of the lighting standard is to reduce energy consumption and carbon emissions while minimizing negative impacts on the UAE economy, environment, and human health. To this end, it is very important to understand the economic, environmental, health, and social implications of the lighting standard for residents and for businesses and governmental agencies.

The residential sector was selected as the focus of this study for several reasons. First, the findings of the EFI—that households account for approximately 57% of energy consumption for the UAE—establish the residential sector as a clear target for improving energy efficiency. In addition, not only does lighting account for a significant percentage of electricity consumption in the residential sector, residential lighting historically has been provided mostly through the use of incandescent lamps, which are the least efficient of the lighting technologies currently in the market. On the other hand, lighting in the commercial, institutional (governmental and public), and industrial sectors is predominantly provided by linear fluorescent lamps, which are among the most efficient of lighting technologies. Compared to the residential sector, the other sectors also tend to be more conscious of energy efficiency and the cost of inefficiency, particularly when there is a financial incentive, as is the case for the commercial and industrial sectors. Furthermore, implementing energy efficiency is easier in the other sectors, where selection of lighting technologies can be made through company or institutional policy decisions, rather than the personal preferences of villa or apartment residents. Finally, if a savings through residential lighting standards can be demonstrated to be material and

[1] EAD was represented by its subsidiary body, the Abu Dhabi Global Environmental Data Initiative (AGEDI)

economical, it stands to reason that this would also be the situation for lighting standards for other sectors.

The decision was made to focus on the carbon component because it accounts for 80% of the country's EF. Depending on location, lighting can account for as much as 20% of the electricity consumed by the residential sector (International Energy Agency [IEA], 2006); thus, an increased emphasis is being placed on establishing energy-efficient lighting (EEL) and associated policy measures. Lighting also has an impact on cooling load because it can generate heat nearly equal to the number of watts consumed. Cooling is the largest electricity-consuming activity in the UAE.

The UAE has the necessary institutional capacity to also develop such a standard, as evidenced by the labeling system for room air conditioners developed by ESMA for the UAE. With an increased emphasis being put on demand-side management (DSM) measures to address the growing gap between demand and supply of energy in the UAE, EWS-WWF and ESMA are seeking to develop a robust energy-efficiency standard, labeling system, and policy framework for lighting in the UAE's residential sector. This standard can then be expanded to cover public and private sectors as the country gains additional experience and stakeholder support.

1.2 Description of Overall Study

Figure 1 depicts the six tasks that comprise the Development of Lighting Standards for the United Arab Emirate*s* study.

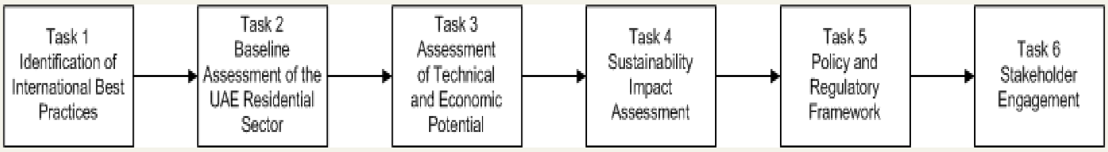


Figure 1. Flow chart for the Development of Lighting Standards for the United Arab Emirates study.

Additional details for each of these tasks are outlined below:

- **Task 1** consists of a review of international best practices. The best practices review will be used to benchmark, identify possible options, and provide a template for the lighting standard developed for the UAE.
- **Task 2** is the baseline assessment of the residential sector in the UAE and includes a profile of the residential lighting sector and an estimate of electricity consumption for residential lighting in the baseline year (see RTI, 2012a).
- **Task 3** consists of an assessment of the technical and economic potential for identified lighting standards. The goal of this assessment is to ensure that the policy or standard is within an acceptable range of cost and benefit in terms of energy savings potential, carbon savings potential, environmental and health trade-offs, recycling, and financial impacts.
- **Task 4** encompasses a sustainability impact assessment, which is a strategic tool to prevent or minimize adverse impacts to current and future generations (see RTI, 2012b). This assessment will cover several areas, including recycling of spent lighting products, mercury waste generation and fate, life-cycle material assessment, cost to consumers, human health effects, public perception, and energy and carbon savings.
- **Task 5** uses the data gathered from the first four tasks (i.e., international best practices, current residential lighting usage, cost-benefit analysis, and environmental impact analysis) to advise stakeholders of policy goals and framework recommendations that will support the reduction of the UAE's carbon footprint. The outcome of Task 5 includes identification of the activities, capabilities, and regulatory frameworks needed for the successful implementation of lighting standards for the UAE. These will range from educational (e.g., workshops and

stakeholder engagement) to enforcement (e.g., establishing compliance monitoring, verification, and enforcement programs).

- **Task 6** focuses on stakeholder engagement. This task is a key component of each of the prior tasks because the success of the study can only be assured if key decision makers across the government and the private and residential sectors are involved throughout the standard development process.

1.3 Organization of Report

Section 2 of this report presents the framework for the analysis and introduces the concepts of technical, economic, and achievable potential for energy savings. **Section 2** also provides an overview of the model developed for the analysis. The technical and economic potential are presented in **Section 3** and **Section 4**, respectively. **Section 5** discusses issues related to the achievable potential, including the supply chain assessment and enforcement. **Section 6** contains a conclusion, including an impact scenario that presents savings over a three-phase deployment option.

2. Overview of the Impact Analysis

This section introduces the metrics used to assess the estimated electricity savings associated with a lighting standard and provides an overview of the analyses that were applied to baseline electricity consumption for residential lighting in the UAE. Additional details on the baseline assessment are provided in the report, *Development of Lighting Standards for the United Arab Emirates – Baseline Assessment* (RTI, 2012a).

2.1 Technical, Economic, and Achievable Potential

Three metrics are commonly used when assessing the potential savings for energy-efficient programs or standards: the technical, economic, and achievable potential of the initiative. As shown in **Figure 2**, the technical potential is the largest, with the economic and achievable potential being subsets of the technical potential. Understanding the influences of these three separate, but related, metrics will the help forecast the impact and inform the design of regulatory policy.

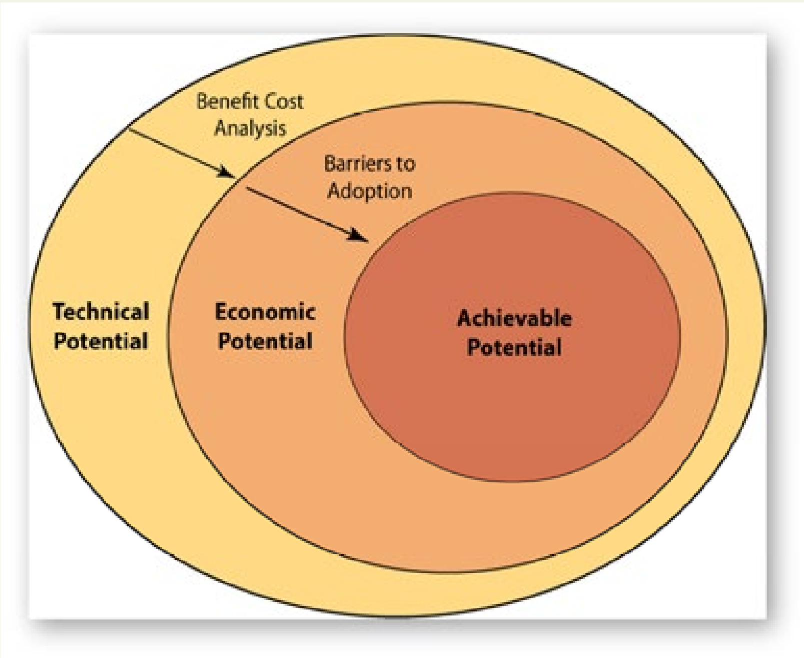


Figure 2. Technical, economic, and achievable potential.

The technical potential is an estimate of the potential savings associated with a specific DSM measure (or combination of measures), assuming that the measure is technically feasible and achieves 100% penetration within the target populations. Technical potential analysis provides the broadest and largest definition of DSM savings and is the basis for determining if further analyses (e.g., economics, adoption) are warranted. Technical potential does not take into account the cost-effectiveness or market acceptance of the DSM measures under consideration.

Economic potential is a subset of the technical potential and represents what is economically cost-effective. At a minimum, the full time-series of benefits must exceed the incremental cost of implementing the energy-efficient measure. In addition, more stringent criteria can be used to define the economic potential, such as meeting the internal rate of return, payback period, or benefit/cost thresholds, reflecting the fact that investment funds have competing opportunities. The economic potential is intended to quantify the share of the technical potential energy savings that are economically viable from either a household or social perspective.

Achievable potential is a subset of the economic potential and represents the savings and/or efficiency level that can realistically be expected. The achievable potential depends on a variety of factors, including the following:

- Implementation strategy: mandatory versus voluntary
- Market conditions and supply chain considerations
- End users' preferences and ability to adapt.

Some of the factors influencing the achievable potential can be subjective and difficult to forecast.

2.2 Household versus Social Costs and Benefits

An important distinction that will be made throughout the analysis is that benefits and costs associated with EELs differ depending on whether one is assessing them from a household versus government (social) perspective. The distinction between public and household benefits and costs will drive the range of policy options and the degree to which market forces (prices or subsidies) versus regulatory forces (codes and standards) are most appropriate to achieve social objectives.

Based on previous studies conducted by RTI, **Table 1** lists the typical factors that influence the benefit/cost analysis from the households and from the societal perspectives. Note that the technical potential is the same from both perspectives. It is primarily the economic potential that differs. This is because not all cost and benefits accrue to the households. The key factor on the cost side is that the cost of electricity is heavily subsidized (to varying degrees) in the UAE. In addition, the environmental benefits from reduced electricity consumption or the environmental costs from increased disposal of toxic substances are not directly realized (in monetary terms) by the household. However, all of these should be considered by the government when assessing the economic and achievable potential.

Table 1. Factors Influencing the Benefits and Cost from the Household versus Government Perspective

Perspective	Monetary Considerations	Non-monetary Considerations
Household	▪ Incremental price ▪ Reduction in electricity bill	▪ Public perception of EEL ▪ Change in light quality ▪ Safety concerns ▪ Special disposal requirements (sorting time) ▪ Availability of lighting products
Government	▪ Incremental price ▪ Energy savings valued at the full cost of delivered electricity ▪ Incremental cost of waste management or recycling (to be determined)	▪ Impact on household (e.g., light quality, safety) ▪ Environmental concerns from disposal ▪ Introduction of more hazardous materials in the country ▪ Environmental benefits for reduced power, including carbon dioxide (CO^2) reductions, and improved air quality ▪ Health benefits from reduced power generation ▪ Public acceptance ▪ Availability of lighting products ▪ Enforcement/ monitoring the market

The difference between the household and societal economic potential can have a driving impact on the regulatory and policy framework to be discussed in the Policy Report. For example, without the implementation of codes and standards, the achievable potential driven solely by household economics may be limited. From a societal perspective, the more desirable outcome is to implement policies that will achieve the largest share of social economic potential as possible.

2.3 Summary of the Baseline and Model

The calculation of technical and economic potential builds on the lighting stock developed in the report, *Development of Lighting Standards for the United Arab Emirates – Baseline Assessment* (RTI, 2012a). **Figure 3** provides a summary of how the baseline lighting stock was developed and includes the following information:

- The number of residential housing units was obtained from the 2005 Census and projected to 2011 using population growth estimates.
- The distribution of housing unit type was obtained from the 2005 Census and is assumed to be constant over time within each Emirate.
- Each type of housing unit is defined in terms of up to 11 room types, based on typical floor plans obtained from real estate and property management companies in the UAE. Each room type (by housing type) has a size (m^2) and an illuminance requirement (measured as lux) that yields a lumens requirement.
- The typical lamp types in a room are then used in conjunction with the lumens requirement to estimate the total number of lamps and the distribution of lamp types within each room. Individual lamps are summed across room types, across housing unit types, and across Emirates to estimate baseline lighting usage.
- Once the number of individual lamps is determined, hours of operation by room type are used to calculate lighting energy consumption.

Figure 3 illustrates the data flow for estimating the number of lamps in a typical kitchen in a medium-sized villa. The lumen requirement for each room is first determined, and then the number of lamps needed to meet this requirement (given the distribution of lamps types within a room) is calculated. Note, in the analysis, the distribution of lamp types within a room type is the same across all types of housing units. The number of lamps differs because the size of the rooms (and hence, lumen requirement) varies across the type of housing units. Also, the room sizes for housing unit type are constant across all Emirates, but the distribution (number) of housing unit types varies across the Emirates.

The distribution of lamps by technology and room types was determined using a combination of the illuminance-based approach and the lamp-based approach. As explained in the Baseline Assessment Report, the lamp-based approach is preferred because it reflects the types and numbers of lamp technologies actually in use. However, it was concluded that there were not adequate data on the existing lamps in use to fully characterize the residential section to the extent needed for this analysis. Instead, data on illuminance criteria were used to supplement the available data on existing lamps.

Data on lamp technologies were taken from the Voluntary Lighting Survey, which is described in Section 6.3.1 of the Baseline Assessment Report. The illuminance data and criteria that were used are described in Section 5.2 of the Baseline Assessment Report. As described in Section 6.4.1 of the Baseline Assessment Report, data on the number of lamps by technology and room type were taken from those survey responses that were complete and internally consistent, and those data were used as the starting point. Using a trial-and-error approach, the data were then adjusted to fill in gaps for all room types and to achieve the target distribution of lamp technologies. Once the final distribution was determined, illuminance criteria were then applied to the relative percentages of each lamp type to determine the specific numbers of lamps by technology, rating, and room type. Additional details are provided in Section 6.4 of the Baseline Assessment Report.

The modeling framework illustrated in Figure 3 was operationalized in a computer model programed in the GAMS software. The model is essentially a multidimensional linear program that accounts for every lamp in the UAE. Each lamp in the baseline is assigned a series of attributes that determine its location and tariff rate (refer to **Section 4.1.2**), operating characteristics (hours/year), energy consumption (watts), price (AED), life expectancy (hours), and potential for EEL upgrade. Based on these characteristics, the model can calculate the total lighting electricity consumption and the electricity savings under different lighting upgrade scenarios.

Data Flow for Technical Potential

Example: Upgrade Kitchen lamps in a medium size villa in Abu Dhabi

Emirate	Total # Units
Abu Dhabi	635,864
Dubai	392,122
Sharjah	301,917
Ajman	74,477
Umm al Quwain	28,285
Ras Al Khaimah	167,604
Fujairah	92,456
Total	1,692,725

Type of housing unit	Units in Abu Dhabi
Studio Apartment	62,777
1-Bedroom Apartment	106,524
2-Bedroom Apartment	121,711
3-Bedroom Apartment	15,227
4+-Bedroom Apartment	3,346
Small villa	18,331
Medium villa	26,439
Large villa	5,590
Part of Villa	11,257
One Story Building	52,389
Public House	69,038
Part of Public House	38,626
Separate Rooms	46,705
Arabic House	0
Others	57,904
Total	635,864

Room Type	Lumens for Medium Villa
Foyer	2,317
Corridor	7,457
Kitchen	15,719
Dining room	11,200
Living room	11,166
Family room	16,281
Washroom	40,585
Bedroom	27,309
Utility room	2,597
Garage	10,606
Exterior	4,340
Total	149,577

Existing Lamp Type	# lamps Kitchen Medium Villa	Upgrade Lamp Type
40 W Incandescent	0.0	8 W HE CFL
60 W Incandescent	0.4	14 W HE CFL
100 W Incandescent	1.2	23 W HE CFL
8 W HE CFL	0.0	None
14 W HE CFL	0.3	None
23 W HE CFL	0.8	None
14 W LE CFL	0.0	8 W HE CFL
23 W LE CFL	0.3	14 W HE CFL
28 W LE CFL	0.8	23 W HE CFL
Linear Fluorescent	8.8	None
Halogen	0.3	8 W HE CFL
Halogen	1.0	14 W HE CFL
LED	0.0	None
LED	1.2	None
Total	14.9	

Hours of Operation in a Kitchen = 2.34 hrs/day

Figure 3. Data flow for lighting baseline.

Figures 4 through 6 summarize the baseline analysis (additional details are presented in the report, *Development of Lighting Standards for the United Arab Emirates – Baseline Assessment*, RTI, 2012a). Baseline lighting energy usage is estimated to be 2,446 GWh per year. As shown in Figure 4, Abu Dhabi is the largest lighting consumer in the UAE, accounting for 35% of usage, followed Dubai and Sharjah, with 25% and 15%, respectively. The remaining Emirates account for approximately 25% of the baseline lighting energy usage

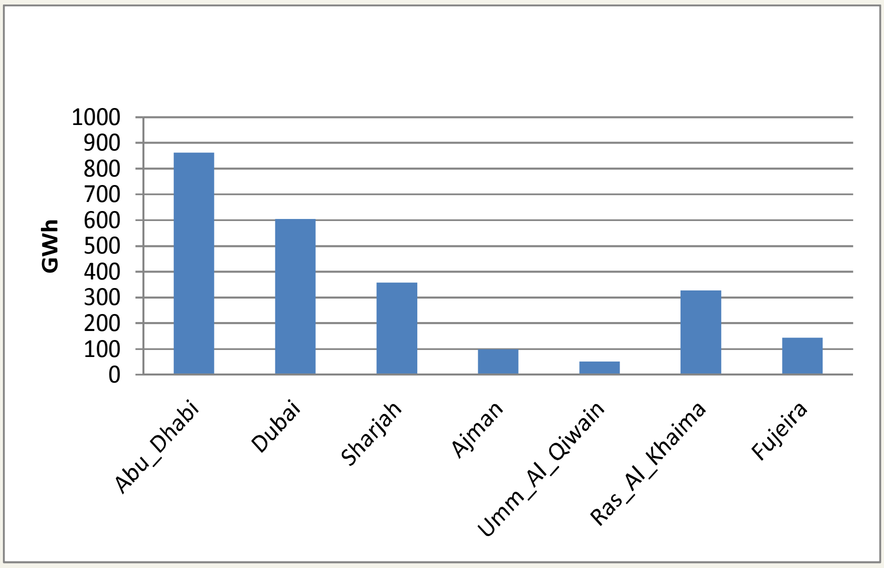


Figure 4. Baseline residential lighting energy use by emirate across the UAE.

Villas account for the largest share of lighting energy usage, totaling 36%. The majority of the consumption is associated with medium-sized villas. Public houses and Arabic Houses (similar to villas) account for an additional approximately 20%. Apartments account for 30% of lighting energy usage in the UAE, with the majority in two-bedroom and one-bedroom apartments.

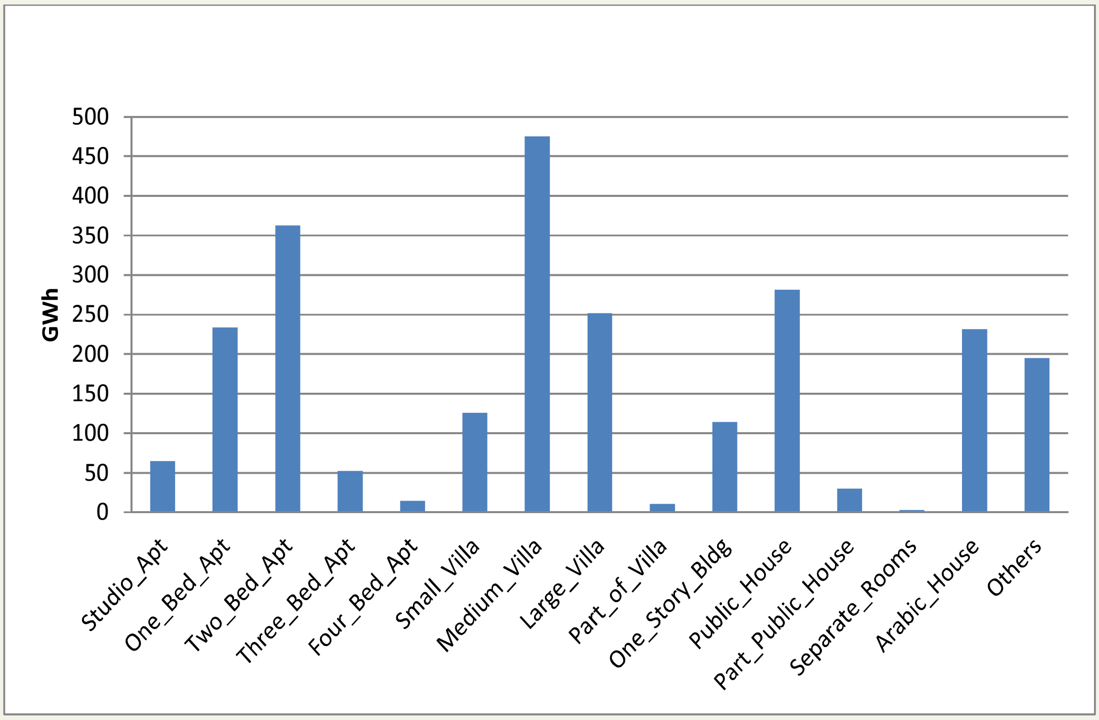


Figure 5. Baseline residential lighting energy use by housing type across the UAE.

Figure 6 and **Figure 7** show the breakdown of the different incandescent, compact fluorescent lamp (CFL), halogen, linear fluorescent lamp (LFLs), and light-emitting diode (LED) lighting technologies. Incandescent lamps account for the overwhelming majority of lighting energy usage, totaling 78%. Within the incandescent, 60-watt lamps represent the bulk of the energy consumption. CFLs account for approximately 8% of the lighting energy consumption with 14-watt CFLs (the equivalent of a 60-watt incandescent) representing the largest share. LFLs and halogens account for approximately 7% each, with minimal penetration of LEDs.

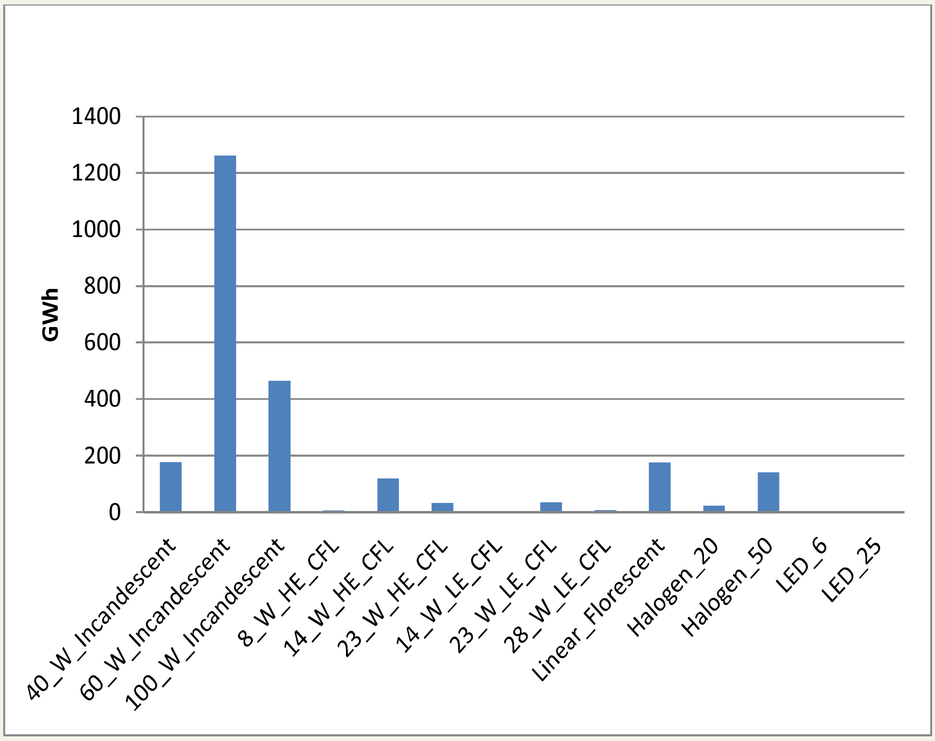


Figure 6. Baseline residential lighting electricity consumption by lamp type.

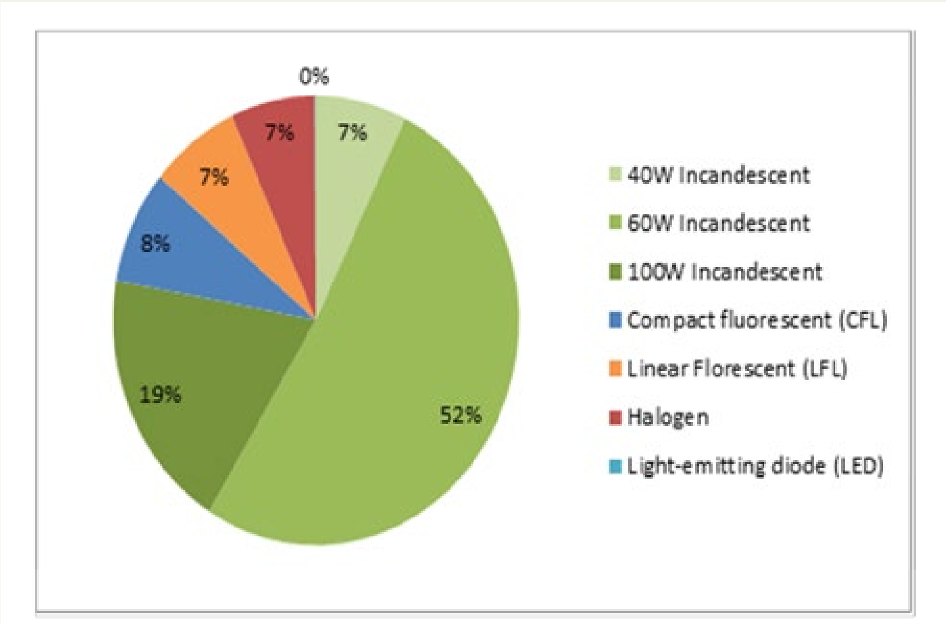


Figure 7. Baseline residential energy use by lighting technology across the UAE.

3. Technical Potential

The technical potential represents the electricity savings if 100% of eligible lamps are upgraded to EELs. This is the maximum savings that can be achieved given the energy-efficiency options being modeled. **Figure 8** presents a step-by-step flow chart of how the technical potential was calculated. As was discussed in the Baseline Report, Emirate-wide population and housing data was used to calculate the number and types of rooms in the residential building stock. Typical lighting requirements and lamp types (obtained from the voluntary survey) were then used to determine the number of lamps by lamp type in the residential building stock. Operating hours (also by room type) were then used to calculate baseline residential lighting energy use.

Families of lamp technologies were then identified for replacement with higher-efficiency lamps (presented in **Section 3.1**). Residential lighting energy use was then recalculated with the EELs to estimate the technical potential.

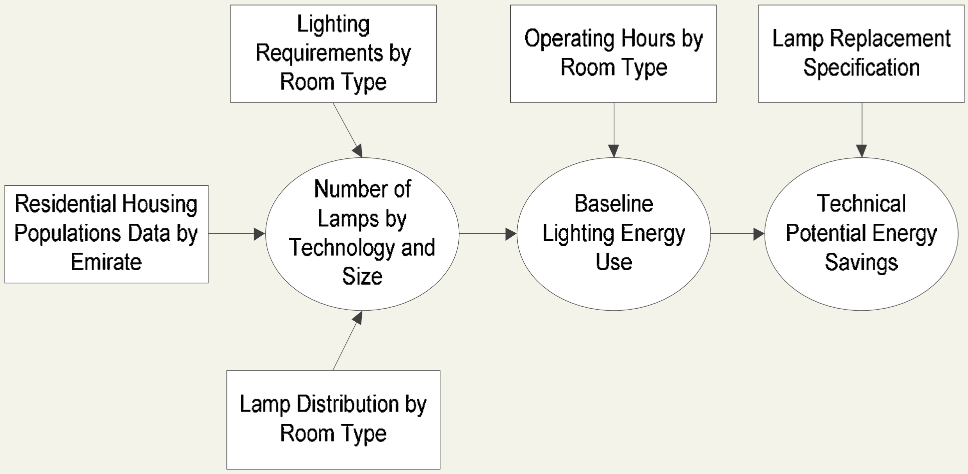


Figure 8. Analysis steps for calculating residential lighting technical potential.

3.1 Lighting Stock and Upgrades Included in the Technical Potential

Given the population of lamps presented in the baseline, families of lamp technologies are targeted for replacement, and this defines the technical potential. **Table 2** lists the baseline lamp types, as well as the associated EEL-type replacement, where applicable. Energy savings from switching to EELs are estimated for incandescent, halogen, and low-efficiency CFL lamps. The model assumes that all upgrades switch to high quality CFL lamps. In general, CFLs use less energy and are lower cost than other EEL options, such as LEDs. Whereas LEDs have longer life expectancies compared to CFLs, their high cost has limited market penetration in most countries. As a result, they are not considered the EEL of choice for the short-term analysis presented in this study.[2]

This analysis focuses on lamps, and specifically on existing incandescent and halogen lamps and the possible high-efficiency replacements for those lamps. Implementation of a residential lighting standard will rely considerably on residential consumers to replace inefficient lighting with high-efficiency lighting, and a standard that targets existing lamps is much simpler to implement than a standard that addresses fixtures or luminaires. If a fixture uses inefficient lamps, the consumer can easily replace it, in most cases, with a high-efficiency lamp. On the other hand, replacing existing

[2] LEDs represent an attractive option with current savings and annualized costs comparable to (but both slightly less than) CFLs. However, as will be discussed in more detail in the Policy Report, the 5 to 7 times higher price of LEDs increases the payback period significantly. For this reason, it is anticipated that CFLs will be the dominate EEL in the market for the near future. However, as LED technology improves in terms of efficiency and price, policy makers will want to consider promoting LED adoption in the future to take advantage of their environmental benefits (less toxic metals).

fixtures, and especially built-in fixtures, requires much greater capital expenditures than replacing lamps. In terms of restricting availability in the market, it also is much easier to limit imports of lamp technologies, which are relatively few in number, than to limit the imports of fixtures. However, for new construction, the situation is quite different. Most apartments and villas include built-in fixtures, which often are linear fluorescent, but may include halogen fixtures. Developing a standard that specifies minimum efficiencies for built-in fixtures in new construction can help ensure the use of high-efficiency lighting in the residential sector. For example, the standard could specify minimum efficiencies for fluorescent ballasts and restrict the use of halogen lighting, and these standards could be incorporated into building standards for new construction.

The baseline assumes that 15% of CFLs are sub-standard (lower luminous efficacy and shorter life expectancy [RTI, 2012a]) and the removal of these low-efficiency CFLs is part of the technical potential. For high-efficiency CFLs, LFLs, and LEDs currently in use, it is assumed that there are no upgrade possibilities that should be included in the technical potential.[3]

This assumption that 15% of CFLs are low quality is based on a study by the U.S. Agency for International Development (USAID) on the quality of CFL lamps market in Asia (U.S. Agency for International Development [USAID], 2007) and data provided by MELA, which, due to confidentiality, cannot be described further in the report. It is assumed that the luminous efficacy of low-quality CFLs is 67% of high-quality CFLs and their average life expectancy is 3,000 hours (compared to 10,000 for high-quality CFLs). These lamp characteristics are also are based on the same USAID report. Uncertainties about the prevalence and performance of low-quality CFLs in the market underscore the need for extensive product quality testing to determine the extent of the problem in the UAE

Table 2. Technical Potential Replacement Lamps

Existing			Upgrade			Energy Savings (Watts)
Lamp Type	Watts	Efficacy (Lumens per Watt)	Lamp Type	Watts	Efficacy (Lumens per Watt)	
Incandescent	40	10.5	High-efficiency CFL	8	52.0	32
Incandescent	60	12.0	High -efficiency CFL	14	55.0	46
Incandescent	100	13.8	High-efficiency CFL	23	60.0	77
High-efficiency CFL	8	52.0	None			
High-efficiency CFL	14	55.0	None			
High-efficiency CFL	23	60.0	None			
Low-efficiency CFL	14	36.9	High-efficiency CFL	8	52.0	6
Low-efficiency CFL	23	40.2	High-efficiency CFL	14	55.0	9
Low-efficiency CFL	28	42.6	High-efficiency CFL	23	60.0	5
Linear Fluorescent	18	60.0	None			
Halogen	20	14.3	LED	6	52.0	14
Halogen	50	14.3	High-efficiency CFL	14	55.0	36
LED	6	52.0	None			
LED	18	56.0	None			

Figure 9 compares the efficiency of different lamp types. As can be seen in Figure 9, incandescent and halogen lamps have efficiencies generally in the range of 10 to 20 lumens/watts. In comparison, high-efficiency CFLs, LEDs, and linear fluorescent lamps have efficiencies in the range

[3] Whereas there are almost always more advanced technologies available, the technical potential does not include newer advanced technologies that are not readily available in the market or would require significant retrofit to fixtures or the building structure.

of 50 to 60 lumens/watts. These ranges are consistent for studies generated by the European Union (see Figure 2 and Figure 3 in en.lighten, 2011). As presented in the conclusion of this report, these efficiency trends by lamp type will form the basis of the minimum energy performance standards (MEPS) to be proposed for UAE residential lighting.

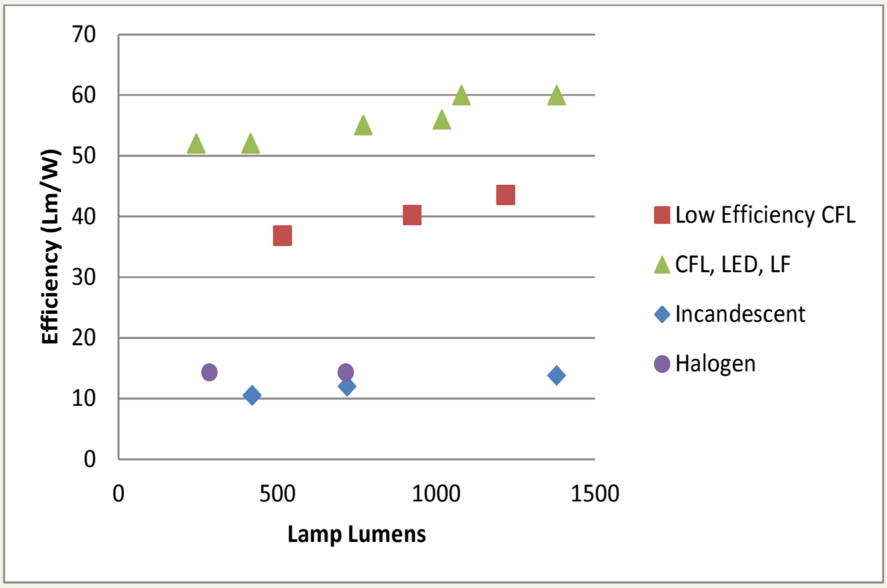


Figure 9. Current/baseline lamp efficiency by lamp type.

3.2 Technical Potential Energy Savings

The direct energy savings from upgrading lighting in the UAE residential sector, as shown in **Table 3**, is estimated to be 1,598.8 GWh, or approximately 65% of total lighting energy usage. **Figure 10** shows the energy savings by lamp type. Incandescent lamps account for the 92% of the energy savings, with 60-watt incandescents accounting for 61%. Even though low-efficiency CFLs represent only 1% of the energy savings, the elimination of these low-efficiency lamps has a significant impact on achievable potential (as will be discussed in **Section 5** of this report). Low-efficiency CFLs are also likely to have higher mercury content compared to high-efficiency CFLs (USAID, 2007).

Table 3. Energy Savings (GWh) by Lamp by Emirate in Baseline Year (2011)

Lamp Type	Watts	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Incandescent	40	52.9	33.5	21.8	5.7	2.7	16.7	7.8	141.3
Incandescent	60	340.3	240.1	140.7	38.8	20.7	131.0	57.3	969.0
Incandescent	100	119.6	88.7	51.1	14.3	8.2	51.4	21.7	354.9
Low-efficiency CFL	14	0.3	0.2	0.1	0.0	0.0	0.1	0.0	0.8
Low-efficiency CFL	23	4.8	3.4	2.0	0.5	0.3	1.8	0.8	13.6
Low-efficiency CFL	28	0.4	0.3	0.2	0.0	0.0	0.2	0.1	1.2
Halogen	20	6.1	4.0	2.5	0.7	0.3	2.1	0.9	16.6
Halogen	50	37.7	24.4	15.2	4.1	2.0	12.4	5.7	101.4
Total		**562.1**	**394.6**	**233.6**	**64.1**	**34.2**	**215.6**	**94.4**	**1,598.8**

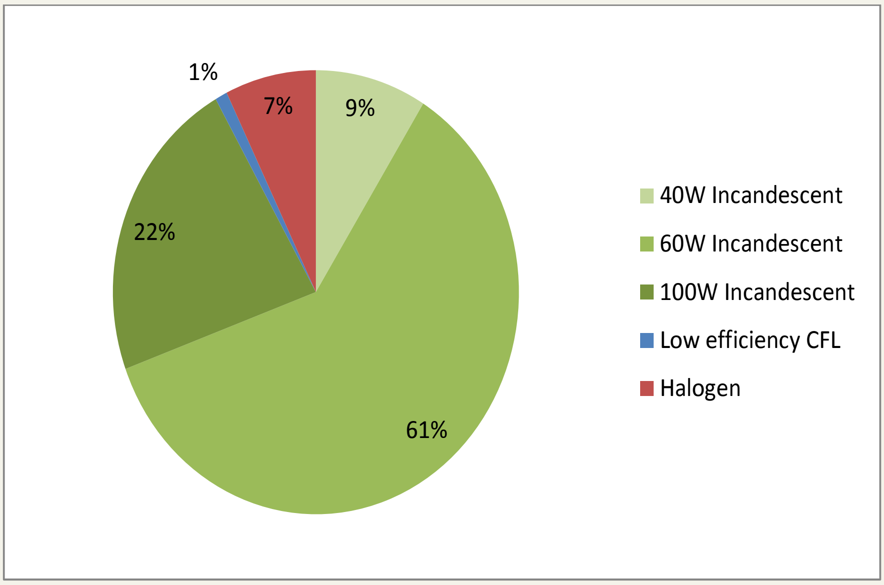


Figure 10. Technical potential by lamp type.

Figure 11 presents the technical potential by lighting type, by Emirate. Again, incandescents dominate the savings potential in all Emirates. The distribution of savings across lamp types is similar, but not identical, across all the Emirates in the UAE. Underlying differences in the population housing types (e.g., villas versus apartments) will lead to slight differences in technical potential across lamp types among Emirates.

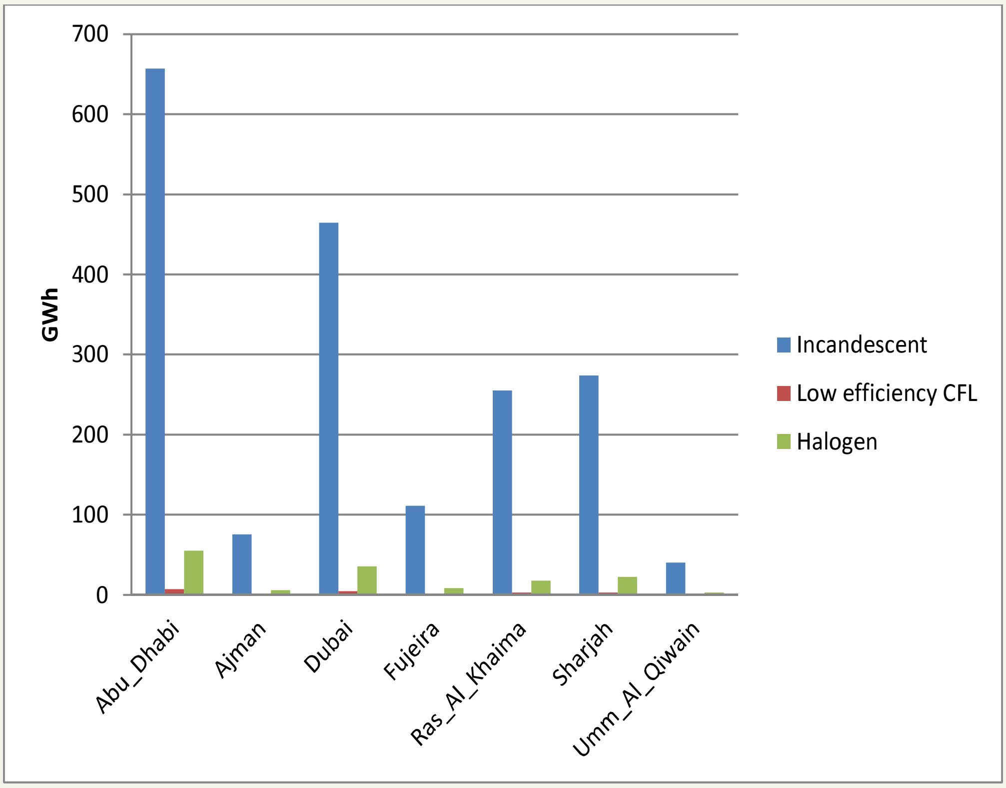


Figure 11. Technical potential energy savings by lamp technology by Emirate.

3.2.1 Indirect Energy Savings from Reduced Cooling Requirements

Lighting systems convert only a fraction of their electrical input into useful light output. A large share of the energy is released directly as heat into a space. Within lamp type, the amount of heat released is roughly proportional to the wattage of the lamp. Any upgrade of the lighting system will thus reduce the amount of heat that must be removed by the air cooling system. This results in air cooling energy savings during the operation of the building. This is also referred to as the cooling bonus and can be calculated using the formula below (inter.Light, Inc., 2012):

$$CB = CS \times MC \div COP$$

Where:

CB	=	Cooling Bonus - Fraction of lighting savings as air cooling savings. This will be used to scale the direct savings from lighting up to the full technical potential
CS	=	Fraction of the year of the cooling season.
MC	=	Lighting load met by mechanical cooling. Some share of the heat generated by lighting dissipates through the walls and widows during the evenings during the winter months, but most is met by the air conditioning system.
COP	=	System's coefficient of performance captures the efficiency of the air conditioning system.

For the UAE, we assume the following:

- The fraction of the year of the cooling season is 10/12=0.83 (residential air conditioners are in use 10 out of 12 months [EAA, 2012])
- The fraction of daily load met by mechanical cooling—assume 90%, with 10% dissipated. (inter.Light, Inc., 2012). This is determined by construction practices and outdoor temperature.
- The air cooling systems coefficient of performance—assume 2.7. This is a conservative assumption because most units are not operating at peak efficiency (EAA, 2012).

Using this formula, the cooling bonus is calculated to be the following:

$$0.82 \times 0.9 \div 2.7 = 0.28$$

This means that for every 1 kWh of lighting energy saved, there is a bonus of 0.28 kWh of air cooling energy. This factor is applied to the technical potential and economic potential throughout the remainder of the analysis. As described below, the direct lamp energy savings presented in Table 3 is multiplied by 1.28 to obtain for full annual technical potential savings.

3.2.2 Total Energy Savings from Lamp Replacement

Table 4 presents the annual technical potential for lighting in the UAE, combining the direct energy savings from the change in lamp consumptions and the indirect cooling bonus. Total energy savings from lamp replacement is 2,046 GWh. All calculations in the following economic analysis use the combined lamp and cooling bonus energy savings.

Table 4. Annual Technical Potential Energy Savings (2011 Population)

Source of Energy Savings	GWh
Lamps (direct)	1598.8
Incandescent replacement	*1465.2*
Halogen replacement	*118.0*
Low-efficient CFL replacement	*15.6*
Cooling (indirect)	447.7*
Total Savings	**2046.4**

*Calculated as 28% of direct lamp energy savings

As shown in **Table 5**, villas and public houses account for the majority of the technical potential. This is followed by the savings potential in apartment buildings. Table 5 was calculated using housing census date for each Emirate, as described in the Baseline Report. In general, the magnitude of technical potential savings is proportional to lighting use for each type of housing unit.

Figure 12 presents the baseline lighting energy usage alongside the technical potential for each Emirate. Note that the red bar is energy savings (thus, remaining energy usage is the difference between the blue and red bar). The percent reduction is similar across all housing types because all housing types currently have a large share of incandescent lamps. Figure 12 is replicated for each Emirate in **Appendix A**. As seen in **Appendix A**, the savings trends are similar for all the Emirates.

Table 5. Annual Technical Potential Energy Savings by Typology by Emirate (GWh) (2011 population – Lamp Savings and Cooling Bonus)

Type of Housing Unit	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Studio Apartment	17.3	16.8	11.6	2.6	0.2	1.3	1.5	51.4
1-Bedroom Apartment	64.4	62.4	43.2	9.5	0.9	4.9	5.5	190.8
2-Bedroom Apartment	101.8	98.7	68.2	15.1	1.5	7.7	8.7	301.6
3-Bedroom Apartment	14.7	14.3	9.9	2.2	0.2	1.1	1.3	43.7
4+-Bedroom Apartment	4.1	4.0	2.7	0.6	0.1	0.3	0.4	12.1
Small Villa	29.9	41.3	12.3	3.9	1.6	13.1	4.8	106.9
Medium Villa	111.8	154.5	46.1	14.6	5.9	49.0	17.8	399.7
Large Villa	59.0	81.6	24.3	7.7	3.1	25.9	9.4	211.0
Part of Villa	6.5	0.6	0.9	0.3	0.0	0.8	0.2	9.3
One-story Building	50.7		8.9	3.2	2.4	17.5	12.6	95.3
Public House	112.6	4.6	28.1	5.4	8.1	45.6	34.7	239.0
Part of Public House	22.4		1.3	0.4	0.1	0.6	1.2	26.2
Separate Rooms	1.4	0.1	0.6	0.1	0.1	0.3	0.2	2.8
Arabic House		24.0	31.7	13.5	17.3	93.9	16.3	196.8
Others	123.0	2.1	9.2	3.0	2.4	13.9	6.1	159.8
Total	**719.5**	**505.1**	**299.0**	**82.2**	**43.8**	**276.0**	**120.8**	**2,046.4**
% Total	**35.2**	**24.7**	**14.6**	**4.0**	**2.1**	**13.5**	**5.9**	**100.0**

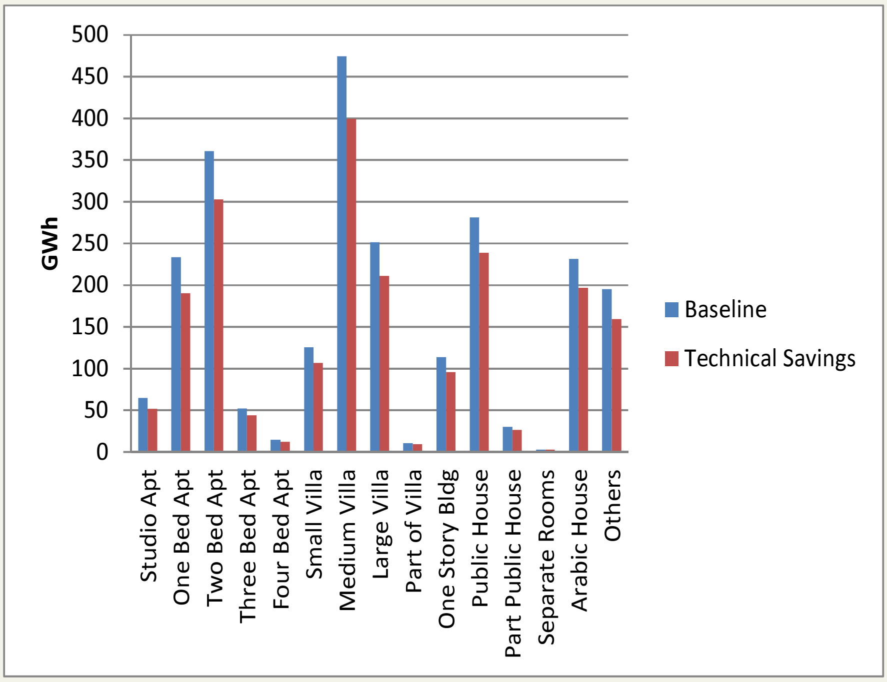


Figure 12. Baseline lighting energy use compared to technical potential savings by housing type.

4. Economic Potential

The economic potential represents the share of technical potential that generates a positive return from investment (i.e., the value of the electricity saved exceeds the incremental price of the lamp upgrade). As shown in **Figure 13,** the economic potential for lamp replacement is conducted by comparing the change in the annualized lamp costs (based on price and life expectancy) with the change in the household's electric bill (based on the tariff rate) to determine if it is profitable for the household to implement the lamp replacement.

The economic potential is also evaluated from both the household's perspective and the government's perspective. In large part, the residential tariff rate determines if upgrading to EELs generates net benefits for the household. The difference between the tariff rate and the full cost of power generation determines the level of subsidy being provided by the government, which drives the government's economic perspective. Note that all benefits calculations include both direct electricity savings from the lamp replacements and the indirect savings associated with the cooling bonus.

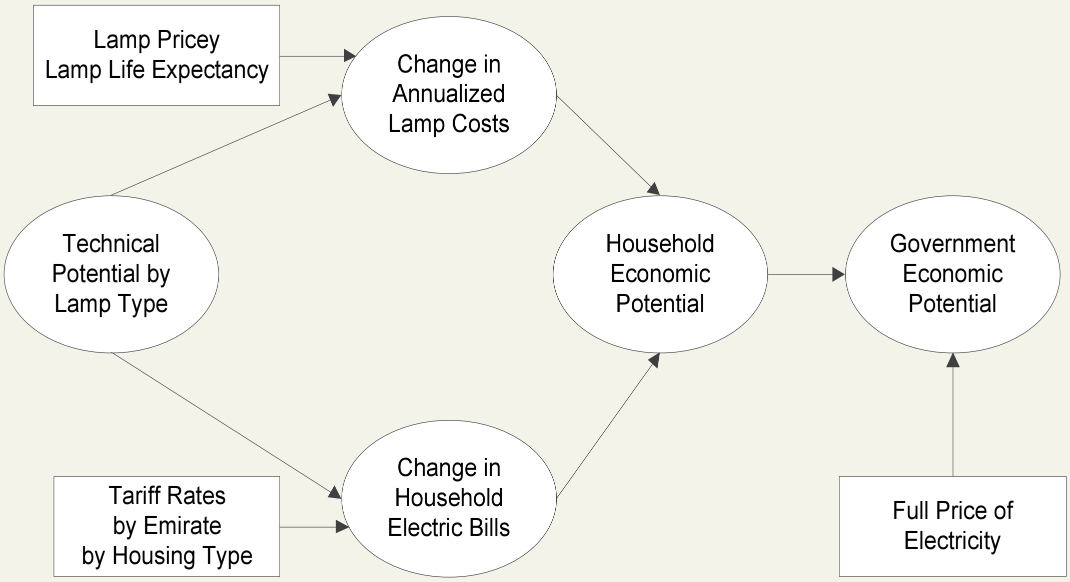


Figure 13. Analysis steps in determining the economic potential.

4.1 Household Benefit/Cost Analysis

The benefit/cost analysis is conducted on an individual lamp basis. Tariff rates vary by Emirate and by nationality (Nationals versus non-Nationals; refer to **Section 4.1.2**). Thus, replacing an incandescent lamp in Dubai has a different impact on a household's electricity bill compared to replacing an incandescent lamp in Abu Dhabi. In addition, within some Emirates (Abu Dhabi and Sharjah), villas owned by Nationals pay a lower tariff rate than apartments. Thus, it is important to account for this level of disaggregation when conducting the household benefit/cost analysis.

4.1.1 Incremental Costs Associated with EELs

The assumed purchase price and estimated life expectancy for lamps is provided in **Table 6**. The purchase price (and energy savings) is annualized for the benefit/cost analysis. Annualized lamp costs are based on life expectancy of lamps and the annual operating hours. As seen in Table 6, households using incandescent lamps may need to purchase more than one lamp per year, but households using CFLs will need to purchase fewer lamps per year because of the longer life expectancy of CFLs. As a result, 8-watt and 14-watt high-efficiency CFLs are actually less expensive than their corresponding 40-watt and 60-watt incandescent lamps when annualized lamp costs are considered. A 23-watt, high-efficiency CFL is slightly more expensive than a 100-watt incandescent, but still comparable on an annualized lamp cost basis. Thus, once energy savings are included, switching from incandescent to high-efficiency CFLs is always economically attractive.

Similarly, low-efficiency and high-efficiency CFLs have comparable annualized lamp costs because of the difference in life expectancy. As a result, when energy savings are included, high-efficiency CFLs are always more economical than low-efficiency CFLs, and the results are the same when comparing halogens with high-efficiency CFLs.

Table 6. Economic Parameters for Lamps

Lamp Type	Watts	Life Expectancy (hrs)	Life Expectancy (years) *	Price (AED)	Annualized Lamp Costs (AED)**
Incandescent	40	1,000	0.9	2.50	2.74
Incandescent	60	1,000	0.9	1.30	1.42
Incandescent	100	1,000	0.9	2.00	2.19
High-efficiency CFL	8	10,000	9.1	13.00	1.42
High-efficiency CFL	14	10,000	9.1	14.00	1.53
High-efficiency CFL	23	10,000	9.1	22.00	2.41
Low-efficiency CFL	14	3,000	2.7	6.50	2.37
Low-efficiency CFL	23	3,000	2.7	7.50	2.74
Low-efficiency CFL	28	3,000	2.7	10.00	3.65
Linear Fluorescent	18	24,000	21.9	3.20	0.15
Halogen	20	2,000	1.8	4.00	2.19
Halogen	50	2,000	1.8	5.00	2.74
LED	6	50,000	45.7	100.00	2.19
LED	18	50,000	45.7	110.00	2.41

* This table uses the assumption of 1,095 hours of operation per year (3 hours per day). Thus, life expectancy by year is calculated by dividing life expectancy by hour by 1,095.

**Annualized lamp cost is calculated by dividing the lamp price by years of life expectancy.

Sources: Lamp life expectancies were obtained from a range of sources, including the U.S. Department for Environment, Food and Rural Affairs, 2009; U.S. Department of Energy, 2012; Limaye et al., 2009; IEA, 2006; OSRAM Opto Semiconductors GmbH, 2009; SBI Energy, 2010; and U.S. Agency for International Development, 2007. Prices were obtained from a survey of markets and shops in Abu Dhabi (RTI, 2012a).

Only incremental purchase costs are included in the economic analysis. As discussed in **Section 3.1**, it is assumed that no replacement of fixtures or other capital investments are needed for moving to EELs. Other assumptions include the following:

- No incremental disposal charges are borne by household
- Potential or perceived lighting quality, safety, or disposal inconvenience are not monetized
- Potential environmental quality or health impacts realized by households are also not monetized.

4.1.2 Household Savings from Lower Electric Bills

Residential tariff structures vary by Emirate. These differences are summarized in **Tables 7 and 8** and are accounted for within the analysis.

- Abu Dhabi has the lowest tariff for residential customers, and tariffs are different for Nationals vs. non-Nationals.
- In 2009, the Sharjah Water and Electricity Authority (SEWA) increased its non-National residential tariff from 20 to 30 fils/kWh. UAE Nationals were not affected and continue to pay the same tariff, which is at 7.5 fils/kWh.

- In 2010, Dubai implemented a slab consumption tariff and increased the average rate for all residential customers.
- The remaining Emirates use a slab consumption tariff established by the Federal Electricity and Water Authority (FEWA), which is slightly less than the one established by the Dubai Electricity and Water Authority (DEWA).

Table 7. Abu Dhabi (ADWEA)[a] and Sharjah (SEWA)[b] Residential Flat Tariffs

Category	ADWEA Residential Tariff (fils/kWh)	SEWA
Nationals	5	7.5
Non-Nationals	15	30

[a] Abu Dhabi Electric and Water Authority
[b] Sharjah Electric and Water Authority

Table 8. Dubai (DEWA) and Federal (FEWA) Residential Tariffs

Slab Consumption (kWh/Month)	DEWA Residential Tariff (fils/kWh)	FEWA Residential Tariff (fils/kWh)
0–2000	23	20
2001–4000	28	24
4001–6000	32	28
6001–above	38	33
Fuel Surcharge	6	0

For slab consumption tariffs, the marginal tariff rate for each typology is used in the economic analysis. This is the rate paid on the last unit of electricity consumed and reflects the saving to a household from a reduction in usage below the baseline consumption. For example, if a household is consuming 3,000 kWh per month and they reduce their lighting electricity usage by 100 kWh per month, the savings in their electric bill would be 100 x 0.28 = 28 AED/month. It is valued at the 2001–4000 slab rate of 28 fils/kWh. Note that the marginal tariff rate is greater than the households' average rate (which is a combination of the different slab rates). Also, for Abu Dhabi and Sharjah, their flat tariff rate is also the marginal tariff rate.

To determine the marginal rate paid, the average monthly electricity consumption was calculated using the DSM Database provided by the Executive Affairs Authority (EAA) of Abu Dhabi. The average monthly consumption was then used to determine the marginal tariff rate from Table 8. **Table 9** provides a summary of the tariff rates used in the economic analysis. Abu Dhabi has the lowest rates, with a residential tariffs ranging from 5 to 15 fils/kWh. Dubai has the highest residential tariff rates, which range from 23 to 38 fils/kWh.

Table 9. Marginal Tariff Rates by Emirate by Typology

Typology	Marginal Tariff Rate (fils/kWh)							
	Average kWh/Month*	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah
Studio Apartment	1,038	15	23	30	20	20	20	20
1-Bedroom Apartment	2,193	15	28	30	24	24	24	24
2-Bedroom Apartment	2,781	15	28	30	24	24	24	24
3-Bedroom Apartment	3,603	15	28	30	24	24	24	24
4+-Bedroom Apartment	4,759	15	32	30	28	28	28	28
Small Villa	8,837	5	38	7.5	33	33	33	33
Medium Villa	19,380	5	38	7.5	33	33	33	33
Large Villa	50,237	5	38	7.5	28	28	28	28
Part of Villa	1,226	5	23	7.5	20	20	20	20
One-story Building	4,293	15	32	30	28	28	28	28
Public House	8,837	5	38	7.5	33	33	33	33
Part of Public House	1,610	5	23	7.5	20	20	20	20
Separate Rooms	884	15	23	30	20	20	20	20
Arabic House	6,730	5	38	7.5	33	33	33	33
Others	18,931	15	38	30	33	33	33	33

*Based on DSM Database provided by the EAA of Abu Dhabi; developed using 2010 monthly residential electricity consumption provided by the Abu Dhabi Distribution Company and the Al Ain Distribution Company.

4.1.3 Benefit/Cost Analysis—Household's Perspective

All the proposed lamp replacements included in the study (as defined in Table 2) were found to be economical for households (i.e., the savings in household energy bills will more than offset the increased price of the EELs). **Table 10** shows the annual net benefits for individual lamps in the Emirates. For example, replacing a 60-watt incandescent with a 14-watt CFL will yield an average net savings of 68 AED per year in Abu Dhabi and an average net savings of 314 AED per year in Fujairah and Ras Al Khaimah.

Instances where lamp replacement is the least economical (although still marginally profitable) are for Abu Dhabi Nationals paying 5 fils/kWh. For tariff rates less than less than 10 fils/kWh, upgrading to EELs has only a modest return for households. However, as will be discussed in the following section, with the full marginal cost of electricity approximately 33 fils/kWh, lamp replacement is always extremely economical from a social perspective. The figure of 33 fils/kWh for the full cost of electricity was provided by the Abu Dhabi Regulation & Supervision Bureau (EAA, 2012) and will be discussed in greater detail in **Section 4.2**.

Table 10. Annual Net Benefit by Lamp by Emirate (AED Saved per Lamp per Year)*

Original Lamp Type	Replacement	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah
40W Incandescent	8W High-efficiency CFL	15.50	38.15	23.13	30.48	42.02	43.86	43.86
60W Incandescent	14W High-efficiency CFL	68.30	257.51	111.57	191.36	295.34	314.37	314.37
100 W Incandescent	23W High-efficiency CFL	22.59	96.98	38.50	71.90	117.42	124.29	124.29
14 W Low-efficiency CFL	8W High-efficiency CFL	0.13	0.25	0.17	0.21	0.29	0.30	0.30
23W Low-efficiency CFL	14W High-efficiency CFL	1.93	4.66	2.41	3.59	5.34	5.69	5.69
28W Low-efficiency CFL	23W High-efficiency CFL	0.23	0.51	0.27	0.40	0.61	0.65	0.65
20W Halogen	6W LED	1.67	4.16	2.29	3.25	4.62	4.89	4.89
50W Halogen	14W High-efficiency CFL	10.43	27.72	15.19	21.53	30.33	32.06	32.06

*Note: These are the annual savings in a household's electric bill from replacing a single lamp (i.e., moving from the original lamp to the replacement lamp specified). Individual lamp savings will then be weighted by the number of eligible lamp replacements to calculate total technical potential for the UAE.

In the aggregate, UAE households will realize significant savings on their electricity bills. **Table 11** shows household savings by Emirate and type of housing. Electricity bill savings in the UAE total 459 million AED per year. Households in Dubai, where tariff rates are highest, account for the largest share of household savings at 167 million AED.

Table 11. Annual Household Electricity Bill Savings by Typology by Emirate for All Lamp Replacements (1,000 AED)

Type of Housing Unit	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Studio Apartment	2,607	3,877	3,495	514	50	263	299	11,105
1-BR Apartment	9,624	17,428	12,905	2,278	220	1,167	1,323	44,945
2-BR Apartment	15,317	27,735	20,538	3,626	350	1,857	2,106	71,528
3-BR Apartment	2,215	4,010	2,969	524	50	269	304	10,342
4+-BR Apartment	615	1,273	825	170	16	87	98	3,085
Small Villa	1,493	15,693	924	1,287	517	4,321	1,574	25,810
Medium Villa	5,584	58,681	3,455	4,814	1,935	16,158	5,886	96,512
Large Villa	2,948	26,089	1,823	2,156	865	7,239	2,637	43,758
Part of Villa	327	128	67	69	5	152	38	785
One-story Building	7,619	0	2,663	906	670	4,912	3,546	20,315
Public House	5,624	1,765	2,103	1,794	2,658	15,023	11,446	40,414
Part of Public House	1,121	0	100	90	27	127	242	1,707
Separate Rooms	208	18	175	26	11	56	49	543
Arabic House	0	9,122	2,375	4,449	5,696	30,996	5,373	58,011
Others	18,380	809	2,749	996	803	4,586	2,016	30,339
Total	**73,684**	**166,627**	**57,166**	**23,699**	**13,873**	**87,213**	**36,936**	**459,280**

Table 12 shows the net household savings by Emirate. The annual increase in lamp expenditures is the change in the individual annualized lamp expenditures summed over all the replacement lamps. In some instances, the annualized replacement lamp costs are positive, and in some cases, they are negative. In total, there is an increase in lamp costs of approximately 8.3 million AED. Annual saving is the households' kWh reduction multiplied by their tariff rate—which is then summed across all households to obtain a total annual reduction in electricity bills of 459 million AED. Note these are the annual benefit after complete replacement of all inefficient lamps.

Net savings are the benefits from reduced electricity bills minus the increase in lamp expenditures. As shown in Table 12, the incremental annual expenditures from moving to EELs are relatively small compared to the electricity bill savings. The benefit/cost ratio for EELs ranges from 23.6 to 90.2, depending on the Emirate and its respective tariff structure. This means that (on average) in Abu Dhabi, for every 1 AED a household invests in EELs, they will save 23.6 AED on their electric bill. The household savings are greater in the other Emirates where tariffs are less subsidized.

Table 12. Net Household Benefit by Emirate (1,000 AED)

Emirate	Annual increase in Lamp Expenditure (a)	Annual Savings from Reduced Electricity Bills (b)	Net Annual Household Savings (b-a)	Benefit/Cost Ratio (b/a)
Abu Dhabi	2,807	73,707	70,900	26.3
Dubai	1,757	166,646	164,889	94.9
Sharjah	1,143	57,130	55,988	50.0
Ajman	301	23,703	23,402	78.9
Umm al Quwain	139	13,882	13,743	100.0
Ras Al Khaimah	860	87,263	86,403	101.4
Fujairah	407	36,949	36,542	90.8
Total	**7,413**	**459,280**	**451,867**	**62.0**

4.2 Social Benefit/Cost Analysis

It is common knowledge that current tariff rates do not cover the full cost of power generation and that, to differing degrees, UAE governments subsidize the provision of electricity. Electricity subsidies provided by the governments are defined as the difference in the full cost of power generation and the revenue received by the distribution companies through electricity tariffs. Thus, from a social perspective, the benefit of adopting EELs is the combined household benefits and the subsidy provided by the governments.

The full ***Average Cost (AC)*** of power generation is used to calculate the reduced subsidy associated with the EELs. The full average cost of electricity is estimated by Abu Dhabi RSB to be around 33 fils/kWh (EAA, 2012), and this figure was confirmed by the Dubai Supreme Energy Council. The model then sums over all the lamps being replaced and calculates the reduction in government subsidies associated with the reduced power generation:

Reduced subsidy = (full AC of electricity * KWh saved) − (revenue from tariffs)

Reduced subsidy = $\sum_{\text{Lamps}}$ (33 fils –tariff) * kWh saved

Table 13 shows the subsidy reduction and full social benefits from EELs for each Emirate. Columns (a) and (b) are replicated from Table 12. The full social benefits are the sum of the household sector benefits and the subsidy reduction from power generation, less the increase in lamp costs. Annual social benefits from EELs for the UAE are approximate 1 billion AED per year for the residential sector.

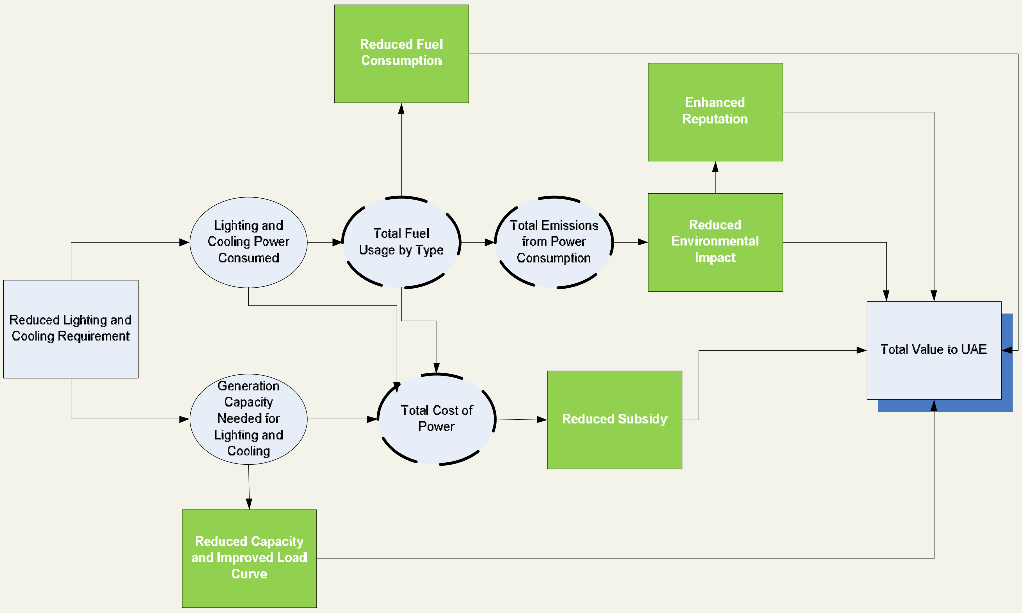
As a point of comparison, the UAE government is projected to spend 3.0 billion AED on healthcare and 8.2 billion AED on education in 2012.[4] Thus, the 0.22 billion AED per year reduction in energy subsidy from EELs could contribute greatly to the provision of government services.

Table 13. Annual Social Benefit by Emirate (1,000 AED)

Emirate	Technical and Economic Potential (GWh)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Abu Dhabi	720	2,807	73,707	163,733	234,633
Dubai	505	1,757	166,646	39	164,929
Sharjah	299	1,143	57,130	41,533	97,521
Ajman	82	301	23,703	3,439	26,841
Umm al Quwain	44	139	13,882	569	14,312
Ras Al Khaimah	276	860	87,263	3,806	90,209
Fujairah	121	407	36,949	2,926	39,468
Total	**2,046**	**7,413**	**459,280**	**216,044**	**667,911**

4.2.1 Additional Social Benefits Associated with EELs

EELs will also generate core benefits to the UAE, in addition to the economic benefits presented in **Section 3**. As shown in **Figure 14**, these benefits span several areas of fiscal, environmental, and social sustainability. Many benefits are directly related to energy, demand, and fuel savings or economic (monetary) benefits. However, there are other benefits, such as environmental improvement or reputational impacts that may not be completely monetized. For example, technology leadership in regional cooling equipment could generate new growth industries for the Emirates. In addition, emission reductions will lead to air quality improvements, which could increase tourism for the Emirates.



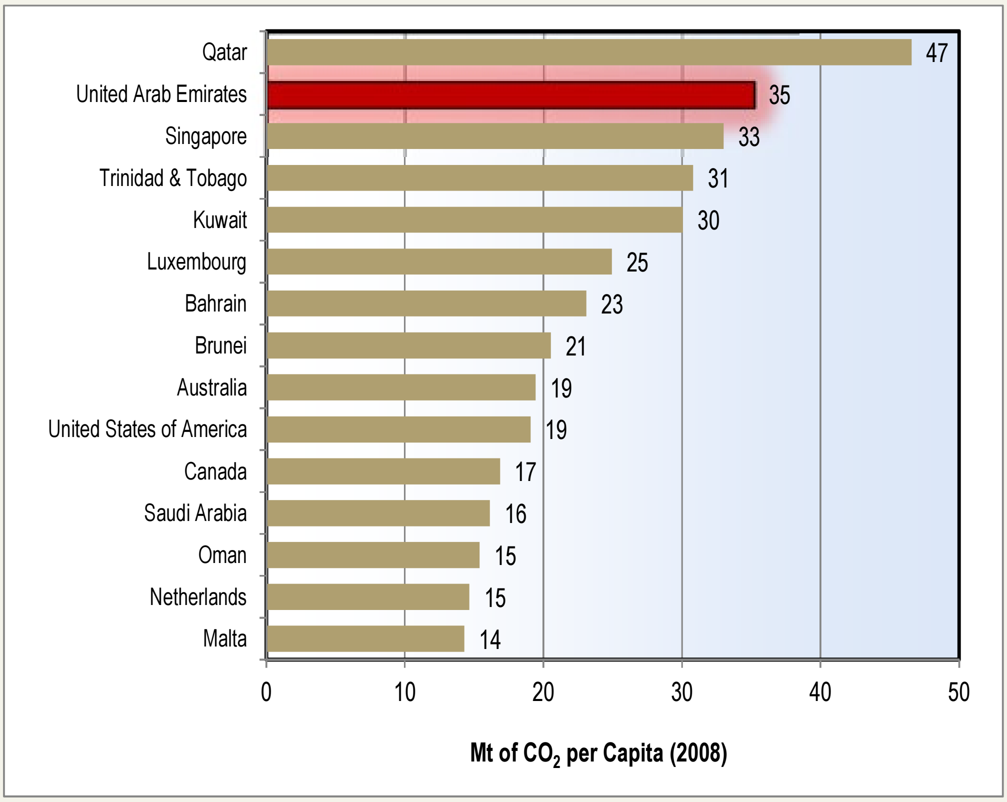
Source: EAA Comprehensive Cooling Plan, 2012

Figure 14. Conceptual benefits of reducing energy consumption due to lighting and cooling.

[4]Source: http://www.khaleejtimes.com/DisplayArticle09.asp?xfile=data/theuae/2011/October/theuae_October287.xml&section=theuae

Not all benefits can be priced in terms of AED, as outlined below.

- Reduced Environmental Impact and Health Benefits
  - The UAE has one of the highest per-capita carbon footprints in the world. As shown in **Figure 15**, the Power and Water sector accounts for a growing share of projected greenhouse gas (GHG) emissions in Abu Dhabi.
  - Energy savings will directly reduce GHG emissions by reducing fuel consumption in the Power and Water sector. As shown in the Sustainability Impact Assessment (SIA) Report, GHG emission reductions are estimated to be approximate 940,000 carbon dioxide equivalents (CO_2e) tonnes per year (RTI, 2012b).
  - GHG emission reductions may have also had additional value if eligible for credits in carbon markets.
  - Air quality improvements will impact health-care costs and worker productivity, which, in turn, impacts the economy.
- Enhanced Reputation
  - The UAE is engaging in a wide range of activities to promote sustainability and energy efficiency and has the opportunity to become a regional leader in designing and implementing programs to promote energy efficiency.
  - Activities such as developing GCC standards for lighting would position the UAE as a regional leader.



Source: World Resources Institute, 2012.

Figure 15. 2008 CO_2 per capita: Top 15 countries.

4.2.2 Additional Social Costs Associated with EELs

As stated earlier, the primary cost considered in the economic analysis was the incremental expenditures by households on higher-priced EELs. However, other household and social factors should also be considered, even if they cannot be quantified or monetized.

The implementation of the standards will likely have costs associated with enforcement of import control. Testing and certification costs to license bulbs for import are typically borne by the producers, of which some share could be passed on to consumers in the form of higher prices. In addition, local governments may need to increase inspection staff at ports and free zones where products enter the UAE markets. These additional workers would need to be trained and be paid an annual salary.

End-of-life management of spent bulbs is another particular area of potential cost increase since all fluorescent bulbs (CFLs, LFLs) use mercury and disposing them in the trash often breaks their fragile glass casing, releasing mercury into the environment. Even if the lamps manage to remain intact after being disposed, these products will likely be broken during transport and end up in landfills, where they could potentially release toxic chemicals into the environment (see SIA Report, RTI, 2012b, for additional discussion).

Although the amount of mercury in a single fluorescent lamp is small, the large numbers of fluorescent lamps in use and eventually discarded will contribute to the amount of mercury that is released into the environment. Therefore, government agencies may need to encourage the recycling of all mercury-containing lamps. Recycling programs can include the following:

- Municipal collection (either pick-up or drop-off sites) and recycling
- Retailer take-back: many retailer stores (e.g., IKEA, Home Depot) are offering in-store recycling
- Mail-back services: some lamp manufacturers and other organizations sell pre-labeled recycling kits that allow businesses and residents to mail used lamps to recycling centers. The cost of each kit includes shipping charges to the recycling center. The consumer fills up a kit with old lamps, seals it, and takes it to the post office or leaves if for his or her postal carrier.
- Hazardous waste could be exported for recycling.

Currently, most of the waste generated in the UAE is disposed of in open dumps (landfills) in the Emirates. Most of these sites are not modern sanitary landfills and do not have liners to prevent leachate from entering the soil and groundwater. Recycling of spent lamps in the UAE has been minimal to date. Only one spent-lamp recycling center was identified in the Emirates. Additional sites would represent additional social costs (even if fully funded by the government).

Mercury in CFLs and LFLs also has the potential to create health risks for households if a mercury-containing lamp is broken and the mercury released. One can be exposed to elemental mercury by touching it, after which it can be eaten and/or absorbed through your skin. More importantly for health, one can also be exposed to mercury through the air, as elemental mercury vaporizes readily and can thus be inhaled into the lungs. Educational programs will likely be needed to inform the public on how to properly handle CFLs and LFLs to prevent breakage and on how to mitigate health impacts if breakage occurs.

5. Achievable Potential

As discussed above, virtually all of the technical potential for EELs in the UAE is economically viable. Even if the import control and recycling costs could be quantified, they would be small compared to the avoided power generation costs. In addition, the achievable potential (i.e., savings actually realized) is likely to be very high given the implementation approach of codes and standards being proposed. Import bans on low-efficiency products are a very effective way to transform the market and achieve the majority of the technical potential.

The following sections present a discussion of the few factors that could limit the achievable potential of EELs in the UAE.

5.1 Supply Chain Factors that Could Affect Achievable Potential for Lighting

Middle East Lighting Association (MELA) members were contacted and indicated that they do not think there will be any supply chain issues that would prevent the market transition to EELs.

International lighting suppliers and other local manufactures are already providing energy-efficient replacements for each standard lamp type and technology and will continue their efforts to improve and broaden EEL portfolios in a range of products. If there were a MEPS for residential lighting in the UAE, lighting producers have said that the installed base will shift quickly to more efficient equivalents, just as they have in other international markets. The older-generation products will be replaced by efficient CFL, LFL, and LED lamps, depending on the application, type, and quality of light required.

The MELA members' EEL product portfolio for residential applications encompasses all categories of residential lamps (many of which are being used in other parts of the world). These efficient alternatives comply with existing global standards for safety and performance. MELA member EEL solutions positioned for used in the UAE are in line with these global standards and are certified by the respective standard entities.

5.2 Enforcement Factors that Could Affect Achievable Potential for Lighting

Enforcement will be the primary factor that could limit reaching full achievable potential. Preventing low-efficiency and White Label products from entering the UAE will be essential. White Label refers to products that are not produced by the brand a product is sold under (i.e., unscrupulous producers or marketers of lamps/lighting products produce/market White Label products and place another brand on the box and/or product). Enforcement of import codes and standards will be key to the success of any EEL initiatives.

Reducing demand for low-efficiency products will also make enforcement simpler and more effective. Thus, it will be important to educate consumers regarding the following:

- Awareness of quality brands versus low-cost brands and the potential disadvantages of low-cost brands, as well as initial cost vs. total cost of ownership
- Knowledge of the benefits of green products
- Low electricity cost = low financial incentive to change to more efficient products
- Awareness for environmental protection.

6. Conclusion

The annual technical potential for energy savings from EELs is estimated to be 2,046 GWh based on the 2011 UAE population. This represents a 65% reduction in direct indoor residential lighting electricity use and a 28% cooling bonus due to reduced air conditioning demand. Ninety-two percent of the savings is associated with the elimination of incandescent lamps with CFLs. The elimination of halogen lamps accounts for 7% of savings, and the elimination of low-efficiency CFLs from the market accounts for the remaining 1% of savings.

All of the EEL options modeled were found to economically viable in that the reduction in electric bills to households more than offset the incremental cost of the EELs. In general, CFLs were cost-effective due the combination of lower energy consumption and longer life expectancy. It is recommended that both of these parameters be confirmed under UAE operating conditions because of their potential to impact the economic analysis.

Total social benefits are estimated to be approximately 668 million AED per year after full adoption of EELs. The household sector benefits (households) are estimated to be 459 million AED per year after full adoption of EELs. Households in Dubai realize the largest share of benefits because they face the highest tariff rate across Emirates. In addition to household benefits, subsidy reductions are estimated to be 216 million AED per year. Abu Dhabi realizes the greatest subsidy reductions because it has the lowest tariff rates. Note that the economic analysis does not include some additional social costs (such as disposal and recycling) or ancillary social benefit (reduced GHG emissions). In addition, some government investment will need to be made, such as educating populations on the benefits and enforcing import restrictions. The policy instruments that need to be put in place will be discussed in the following Policy Report.

The achievable potential (i.e., savings actually realized) is likely to be very high given the implementation approach of codes and standards being proposed. Import bans on low-efficiency products are a very effective way to transform the market and achieve the majority of the technical potential; however, a smooth supply chain transition is key for achieving benefits in the short run, and enforcement is essential for achieving benefits in the long run.

The following is an evaluation of how MEPS could potentially be phased in the UAE. They are similar to policy objectives put forth in the European Union and by en.lighten promoting efficient lighting for developing and emerging countries.

6.1 MEPS Option, Potential Savings, and Economic Benefits

Based in the analysis of technical, economic, and market potential, three phase-out strategies are presented for consideration. The phase-out strategies are also referred to as MEPS because this is frequently the main requirement of the standard (other factors involve quality and safety specification).

Table 14 presents two technology-based transition scenarios to be considered. These two scenarios are described in more detail below, along with their potential economic and environmental impact.

Table 14. Transition Scenarios

	Technologies Phased Out	Transition to
Scenario 1	Incandescent, halogens, and low-efficiency CFLs	High-efficiency CFLs and LEDs
Scenario 2	Incandescent, halogens, and low-and high-efficiency CFLs	LEDs

6.1.1 Scenario 1: Phase out of Incandescent, Halogens, and Low-efficiency CFLs

Scenario 1 would phase out three families of low-efficient lamps over a three year period as shown in **Table 15**. The scenario would likely be implemented as a series of increasingly stringent MEPS. The phasing would help minimized transaction costs and social burdens by allowing both suppliers and consumers to gradually adjust over the 3-year time period.

Table 15. Scenario 1: Phase out of Incandescent, halogens, and low-efficiency CFLs

	Timing of Phase Out	Technologies Phased Out	Technologies Allowed After Phase-Out
Phase 1	2013	Incandescent	Halogens, CFLs (high and low efficiency), LEDs, and LFLs
Phase 2	2014	Incandescent and halogens	CFLs (high and low efficiency), LEDs, and LFLs
Phase 3*	2015	Incandescent, halogens, and low-efficiency CFLs	High Efficiency CFLs, LEDs, and LFLs

*The timing (third year) of the phase-out of low-efficient CFLs in this scenario is based on efficiency criteria. However, it may be desirable to phase-out low-efficiency CFLs in the first year based on their mercury content under health and safety criteria.

Figure 16 presents the MEPS associated with each phase of the EEL implementation. As can be seen in Figure 16 and the corresponding **Table 16**, lamp efficiency increases with each subsequent phase. Upon the implementation of Phase 3, only EEL equivalent in efficiency with CFLs, LEDs, and linear fluorescents are allowed into the country.

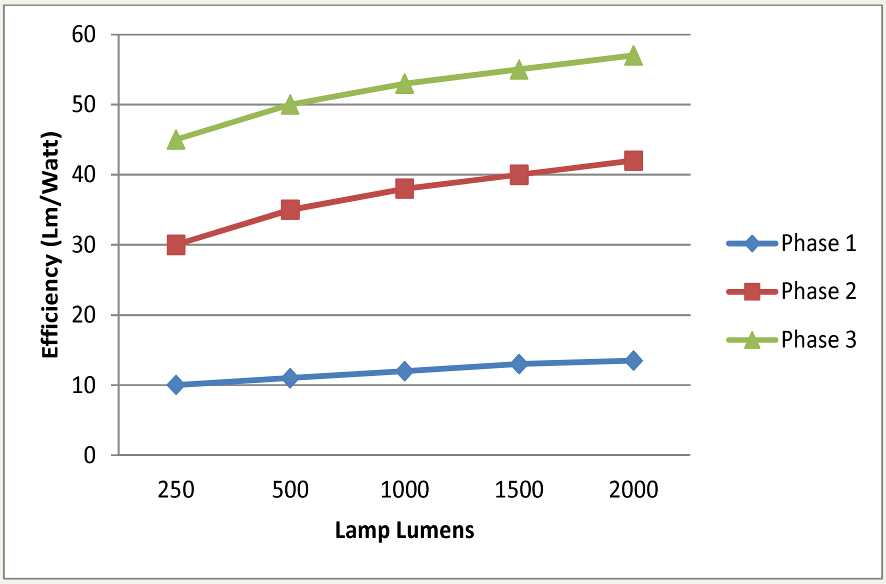


Figure 16. Lamp efficiency by lamp type.

Table 16. Minimum Efficiency Performance Standards for Phase Out-Options

Light Output (Lumens)	Phase 1		Phase 2		Phase 3	
	Power (Watts)	Efficiency (lm/Watt)	Power (Watts)	Efficiency (lm/Watt)	Power (Watts)	Efficiency (lm/Watt)
250	25.0	10.0	8.3	30.0	5.6	45.0
500	45.5	11.0	14.3	35.0	10.0	50.0
1000	83.3	12.0	26.3	38.0	18.9	53.0
1500	115.4	13.0	37.5	40.0	27.3	55.0
2000	148.1	13.5	47.6	42.0	35.1	57.0

The incremental savings potential for each option is presented in **Table 17** and **Figure 17**. As can be seen in the figure, the overwhelming majority of the savings are realized in the first year with the phase-out of incandescent lamps. The phase-out of halogens and low-efficiency CFLs represent a relatively small saving potential due to their current low market share.

Table 17. Annual Energy Savings by Phase-Out Option (GWh)

	Phase_1	Phase_2	Phase_3	Total
Abu Dhabi	656.4	56.1	7.1	719.5
Dubai	463.8	36.4	4.9	505.1
Sharjah	273.5	22.6	2.9	299.0
Ajman	75.4	6.1	0.8	82.2
Umm Al Qiwain	40.4	2.9	0.4	43.8
Ras Al Khaima	254.8	18.2	2.7	276.0
Fujeira	111.2	8.5	1.2	120.8
Total	**1875.5**	**151.0**	**19.9**	**2,046.4**

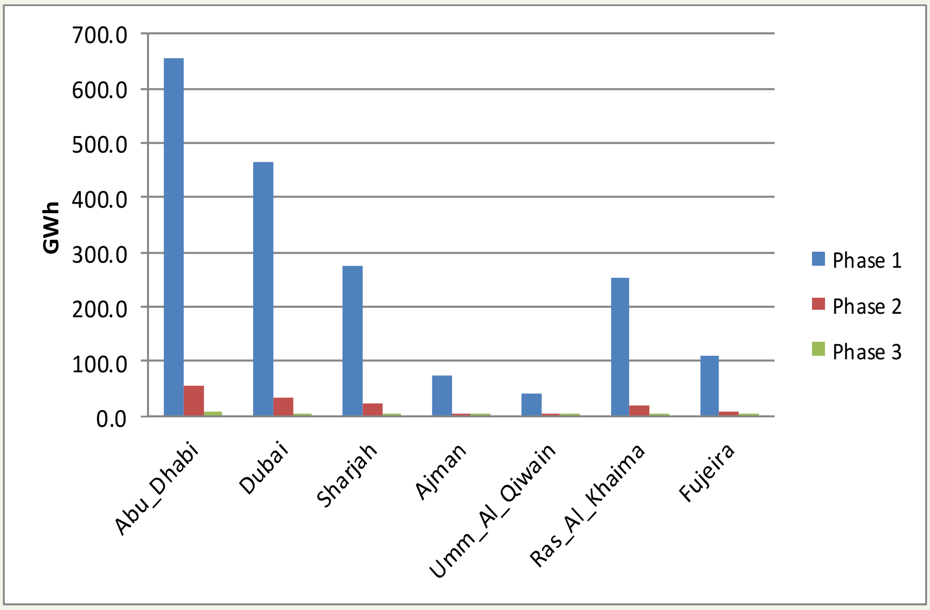


Figure 17. Energy usage reductions by phase and by Emirate.

Similarly, the economic benefits to households and governments are primarily associated with the initial phase-out of incandescents. **Table 18** shows the cumulative savings/benefits, and **Table 19** shows the incremental savings/benefits associated with each phase. **Appendix B** presents the cumulative annual social benefits by phase-out option for each individual Emirate.

Additional policy scenarios will be assessed as part of the Policy Report. In addition, policy instruments and activities will be discussed that will be needed to ensure a successful implementation of the MEPS.

Table 18. Cumulative Annual Social Benefit by Phase-Out Option (1,000 AED)

Timing	Total Annual Energy Savings (GWH)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	1,875	2,268	420,840	198,072	616,644
Phase 2	2,027	5,366	454,807	213,940	663,382
Phase 3	2,046	7,413	459,280	216,044	667,911

Table 19. Incremental Annual Social Benefit by Phase-Out Option (1,000 AED)

Timing	Total Annual Energy Savings (GWH)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	1,875	2,268	420,840	198,072	616,644
Phase 2	151	3,097	33,967	15,868	46,738
Phase 3	20	2,048	4,473	2,104	4,530
Total	**2,046**	**7,413**	**459,280**	**216,044**	**667,911**

Environmental impacts associated with the phase-outs are presented in **Table 20** and make significant contributions to the UAE's sustainability and environmental goals. Details on the underlying calculations for the emission reductions, as well as other sustainability benefits, are discussed in the SAI Report.

Table 20. Potential Emissions Reduction from Lamp Replacement.

	CO_2-eq (tonnes/year)	NO_x (tonnes/year)	SO_x (tonnes/year)
Incandescent Phase-out	861,669	4,659	18,001
Halogen Phase-out	67,960	367	1,420
Low-efficiency CFL Phase-Out	9,139	49	191
Total	**938,768**	**5,075**	**19,612**

The timing of the energy savings is a function of when the ban is initiated and how long it takes for the existing stock of lamps to be replaced based on natural failure.[5] **Table 21** shows the life expectancy for the different lamp types being phased out. As shown in the table, it will take slightly less than1 year for all of the existing stock of incandescent lamps to fail and be replaced. However, it will take 2.7 years for all the existing low-efficient CFLs to fail and be replaced. In addition, under this scenario, low-efficient CFLs are not banned until the third year of the standard. Thus, full annual savings are not realized until the sixth year of the standard. This timing is shown in **Figure 18**. The top three graphs in Figure 18 show the annualized savings rates for each of the three lamp types being phased out. The bottom graph is the total annualized savings rate (sum of the top three graphs).

[5] The Policy Report will discuss the policy options for accelerating replacement of inefficient lamps through exchange programs.

Table 21. Life Expectancy and Replacement Rate by Lamp Type

Lamp Technology	Life Expectancy (hours)	Life Expectancy* (years)
Incandescent	1000	0.9
Halogen	2000	1.8
Low-efficiency CFL	3000	2.7

*Assuming 3 hours per day of use

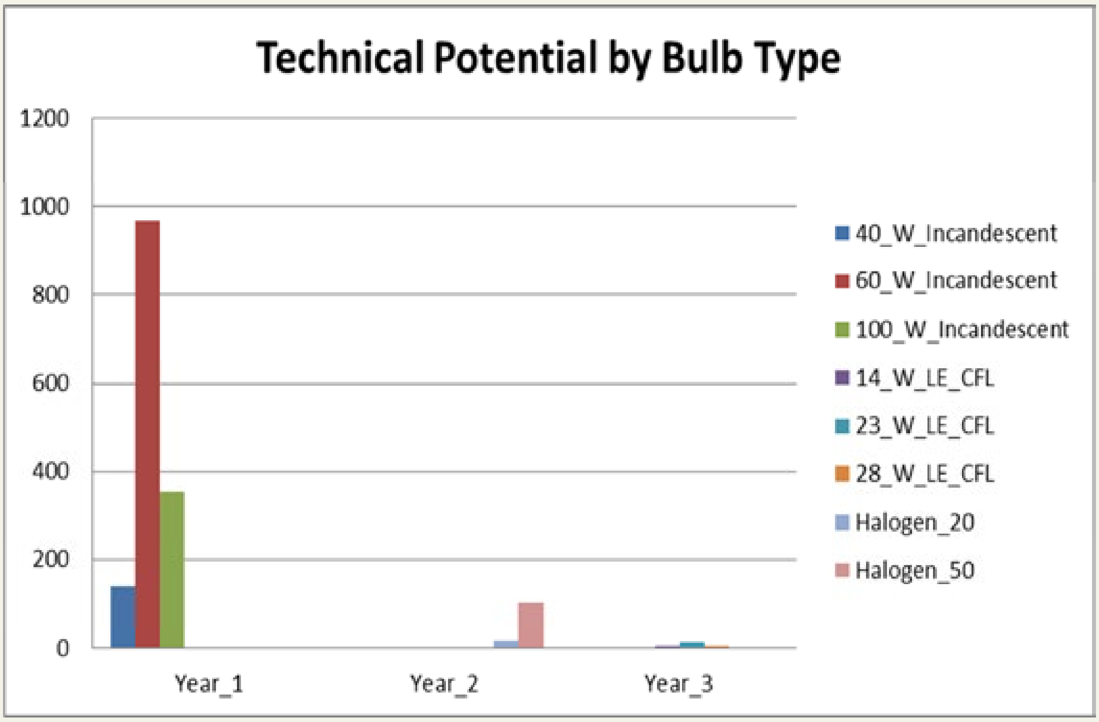


Figure 18. Scenario 1: CFL transition timing of annualized energy savings.

6.1.2 Scenario 2: Transition to LEDs

Scenario 2 contains the same three phase-outs of incandescent, halogen and low-efficient CFLs as in Scenario 1. The difference is that the transition is made to LEDs as opposed to high-efficient CFLs. **Tables 22 and 23** present the results. A summary of the differences between Scenario 1 and Scenario 2 is as follows

- Energy saving of 2,046 GWh is unchanged under the LED scenario because LEDs and CFLs have approximately the efficacy.
- Annualized incremental lamp expenditures increased from 8.2 to 10.1 million AED under the LED scenario, but are still minimal compared to the benefits
- First cost (up-front costs) are 5-7 times greater for LEDs compared to CFLs and the technology is not as mature.
- Benefits to households and government is unchanged under the LED scenario
- Air emission reductions are unchanged compared to the CFL replacement scenario
- The timing of the scenario is the same
- 26 kg of mercury waste is avoided by transitioning to LEDs instead of CFLs

Table 22. Scenario 2: LED - Incremental Annual Social Benefit by Phase-Out Option (1,000 AED)

Timing	Total Annual Energy Savings (GWH)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	1,875	3,103	420,840	198,072	615,809
Phase 2	151	4,237	33,967	15,868	45,598
Phase 3	20	2,802	4,473	2,104	3,775
Total	**2,046**	**10,141**	**459,280**	**216,044**	**665,183**

Table 23. Scenario 2: LED - Potential Emissions Reduction from Lamp Replacement

	CO_2.eq (tonnes/year)	NO_x (tonnes/year)	SO_x (tonnes/year)
Incandescent Phase-out	775,502	4,193	16,201
Halogen Phase-out	61,164	330	1,278
Low-efficiency CFL Phase-Out	8,225	44	172
Total	**844,891**	**4,568**	**17,651**

6.1.3 Alternative Lighting Usage Rates (ESMA Survey)

As described in the Baseline Report, lighting usage rates used in the analysis are a significant determinant of the energy, economic, and environmental impact estimates. Our analysis uses a relatively conservative estimate based on a study conducted by the U.S. Department of Energy. For several reasons, it may underestimate residential lighting usage in the UAE, but it was selected because it provides the best documented and most defensible usage rate estimates.

An alternative source of information for residential lighting use in the UAE is provided from an informal survey that ESMA conducted with its staff in 2012. ESMA collected lighting usage information on 42 residences from a combination of National and non-National households. As shown in the Baseline Report, the reported lighting usage per day was on average 7.5 hours, which is higher than the other studies. One explanation for the relatively high usage rates is that the ESMA survey did not account for the possibility that not all the lamps in a room are on at any given time. For example, a kitchen may have 20 to 30 lamps of different types, but only about half of them may be on at any given time. Thus, if lights are on the kitchen for 6 hours, this translates into 3 hours when applied to the full set of lamps. The international studies used as the basis for the main analysis are based on actual metered usage and are able to capture these factors.

Table 24 and Table 25 present the energy and economic impacts when the ESMA usage hours are applied to the study models (based on transition to CFLs). As seen in the tables, the impacts increase approximately four fold to 8,138 GWhs and social benefits of 2.6 billion AED per year.

Table 24. Alternative Usage Rates: Annual Energy Savings by Phase-Out Option (GWh)

	Phase 1	Phase 2	Phase 3	Total
Abu Dhabi	2,569.6	257.4	27.8	2,854.9
Dubai	1,814.3	168.8	19.4	2,002.5
Sharjah	1,071.3	103.9	11.5	1,186.7
Ajman	295.8	28.1	3.2	327.0
Umm Al Qiwain	160.2	14.0	1.7	175.8
Ras Al Khaima	1,008.8	87.8	10.5	1,107.1
Fujeira	439.3	40.0	4.6	483.9
Total	7,359.3	700.0	78.6	8,137.9

Table 25. Alternative Usage Rates: Incremental Annual Social Benefit by Phase-Out Option (1,000 AED)

Timing	Total Annual Energy Savings (GWH)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	7,359	11,314	1,652,161	776,411	2,417,258
Phase 2	700	14,259	157,589	73,418	216,748
Phase 3	79	8,043	17,640	8,290	17,887
Total	**8,138**	**33,616**	**1,827,390**	**858,118**	**2,651,892**

6.2 Recommendations

Residential lighting standards that phase-out incandescent, halogen, and low-efficiency CFLs could generate significant economic benefits for the UAE and should likely be the focus of the initial standard. As shown in **Table 26**, social benefits (benefits to households and government) associated with phasing-out these three categories of inefficient lamps are estimated to be AED 668 million per year based on switching to high-efficiency CFLs. Subsidy reduction to the government would account for AED 216 million of these benefits, with the remaining AED 459 million going to households in the form of lower electricity bills. Switching to LEDs generates approximately the same benefits because LEDs are approximately the same efficient (lumens/watt) compared to CFLs.

The social payback period for a wholesale upgrade to CFLs would be approximate 1.1 year. This means that the full cost of switching incandescent, halogen, and low-efficiency CFLs to high-efficiency CFLs would be covered by the reduction in electricity production costs in 13 months. From government's perspective, if they were to fully fund the transition with subsidy reductions, the payback period would be approximately 3.4 year. Both the social and government payback periods strongly support aggressively moving forward with residential lighting standards.

LEDs also represent an attractive option with current savings and annualized costs comparable to (but both slightly less than) CFLs. However, as shown in Table 26, LED's price is 5 to 7 times higher than CFLs which increases the payback period from the social and government perspective to 8.5 and 26.2 years, respectively. Wholesale upgrade to LEDs would cost over AED 5 billion. For this reason, it is anticipated that CFLs will be the dominant EEL in the market for the near future. However, as LED technology improves in terms of efficiency and price, policy makers will want to consider promoting LED adoption in the future to take advantage of their environmental benefits (less toxic metals).

Table 26. First Cost of Full Lamp Replacement and Associated Payback (AED 1,000)

	First cost replacement to CFLs	First cost replacement to LEDs
Upgrade cost	732,704	5,659,402
Subsidy reduction (Annual government benefits)	216,044	216,044
Government Pay back (years)	3.4	26.2
Social Benefits (Annual Household + Government)*	667,911	667,911
Social Payback (years)	1.1	8.5

*Note: lamp costs are not removed

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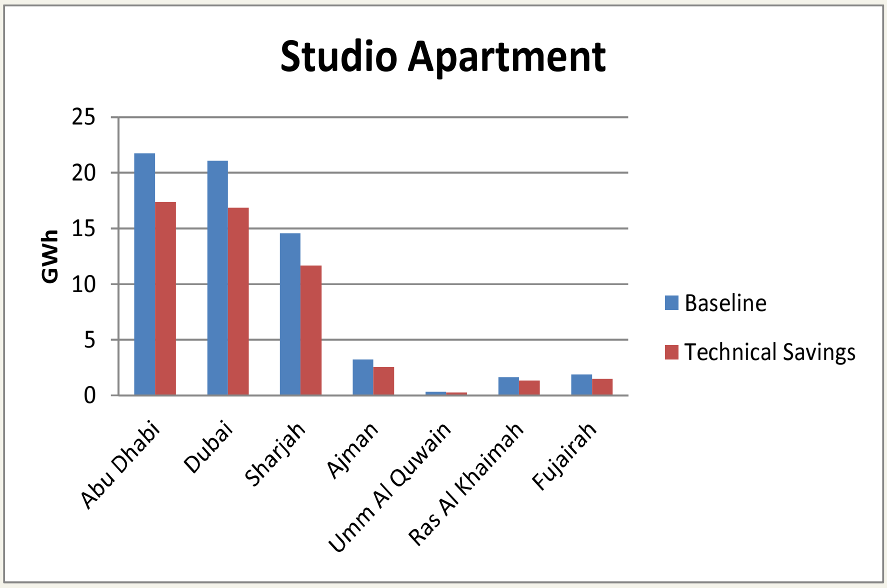
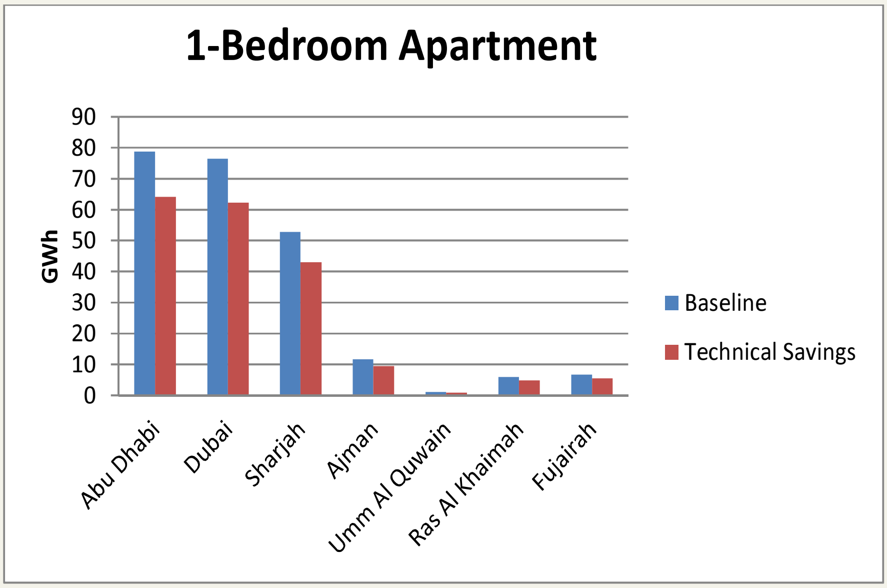
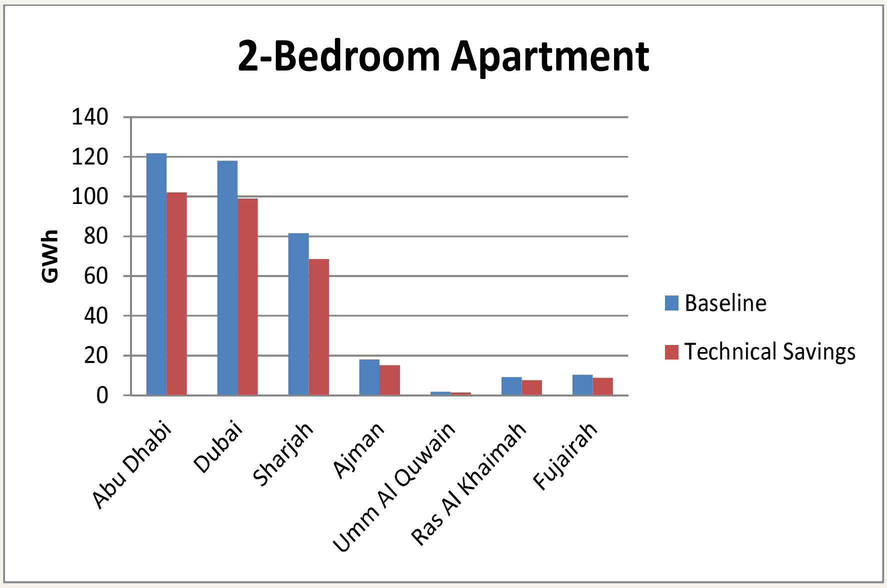
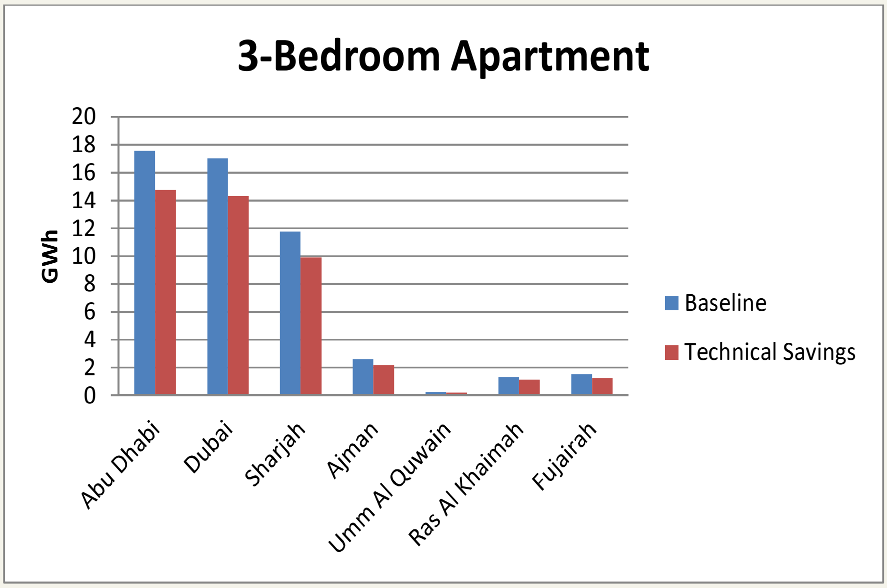
Appendix A: Comparison of the baseline energy use versus the potential technical savings per Emirate by housing type.






2-Bedroom Apartment
GWh
140
120
100
80
60
40
20
0
Abu Dhabi
Dubai
Sharjah
Ajman
Umm Al Quwain
Ras Al Khaimah
Fujairah
Baseline
Technical Savings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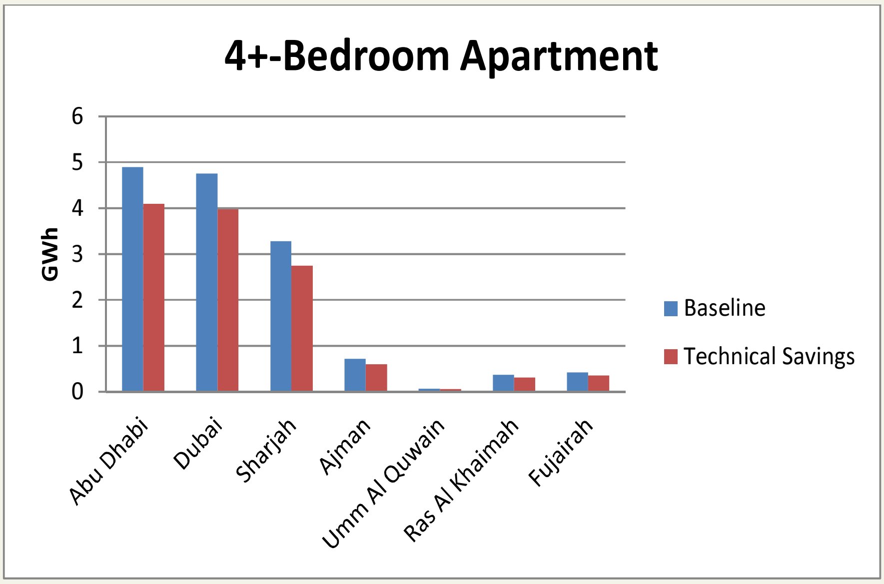
Ajman
Umm Al Quwain
Ras Al Khaimah
Fujairah
Baseline
Technical Savings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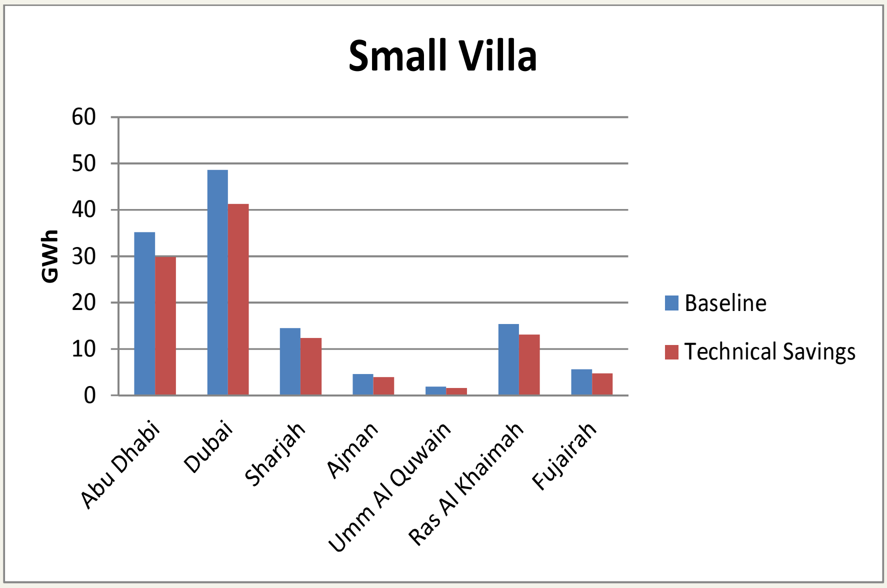
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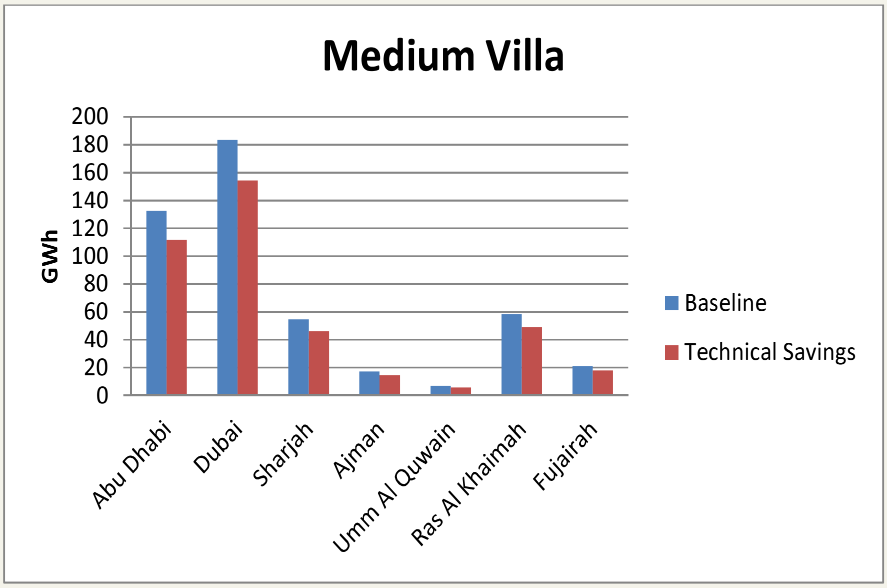
Baseline
Technical Savings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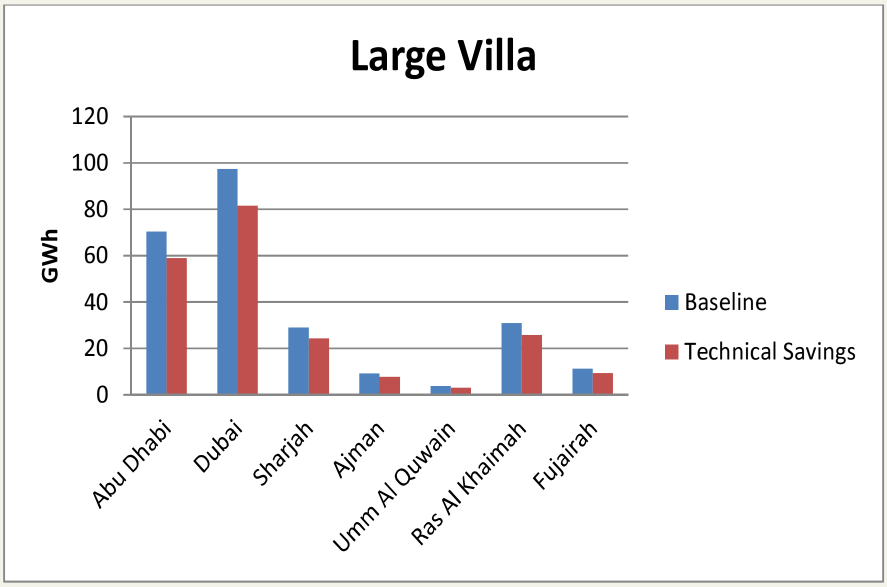
Fujairah
Baseline
Technical Savings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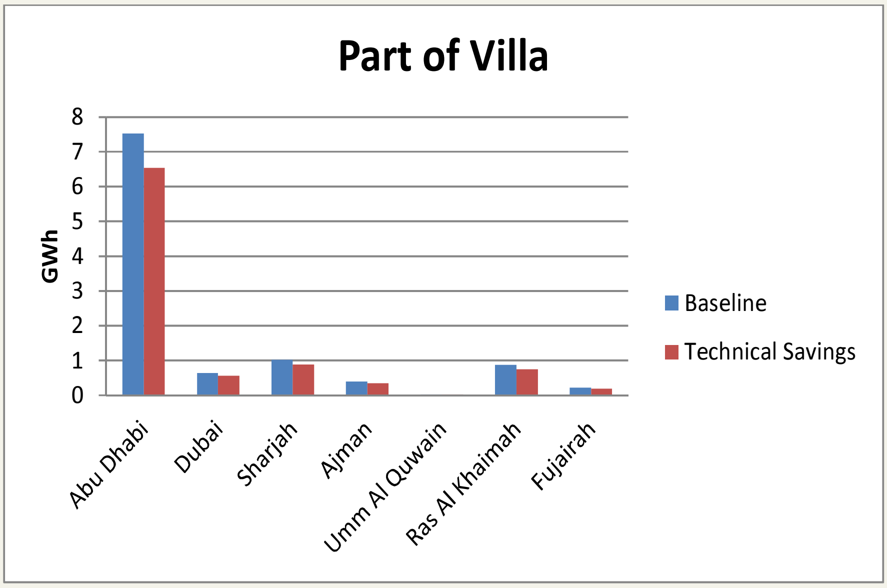
Fujairah
Baseline
Technical Savings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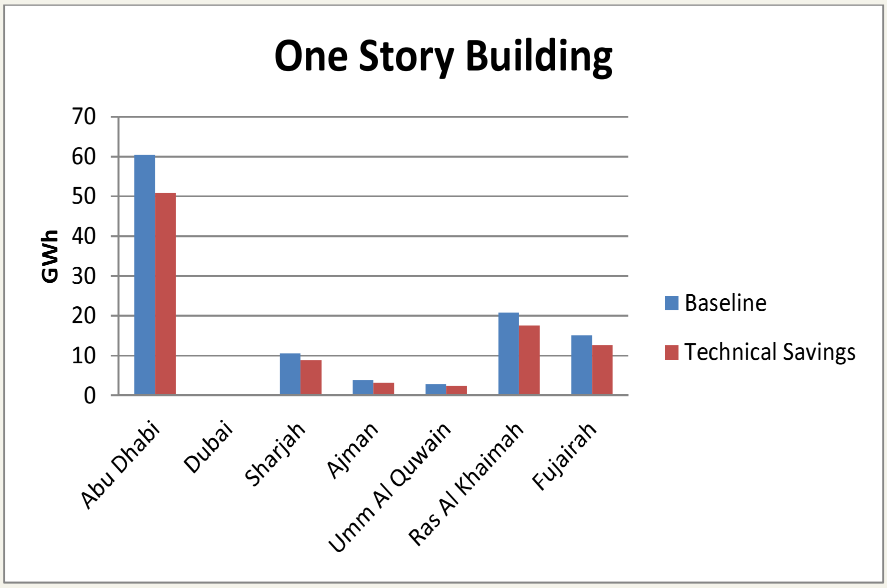
Fujairah
Baseline
Technical Savings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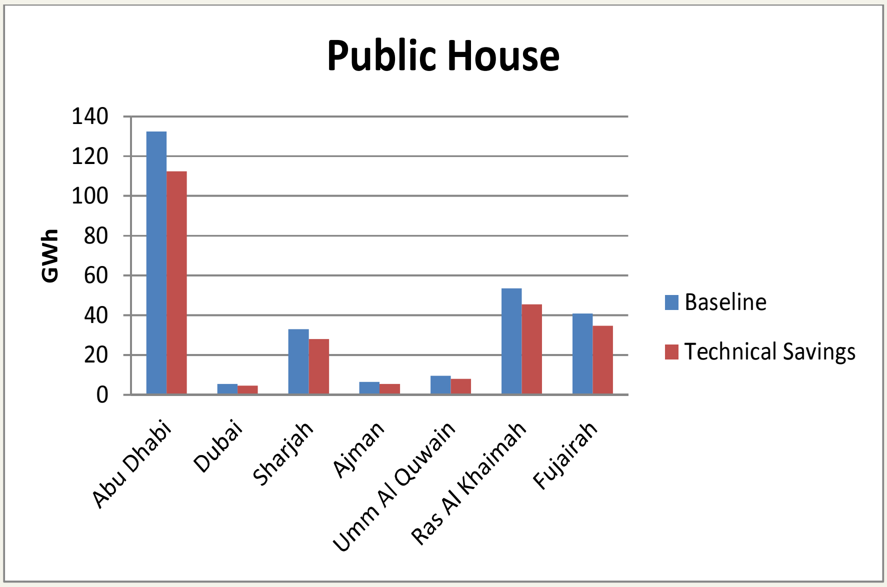
Fujairah
Baseline
Technical Savings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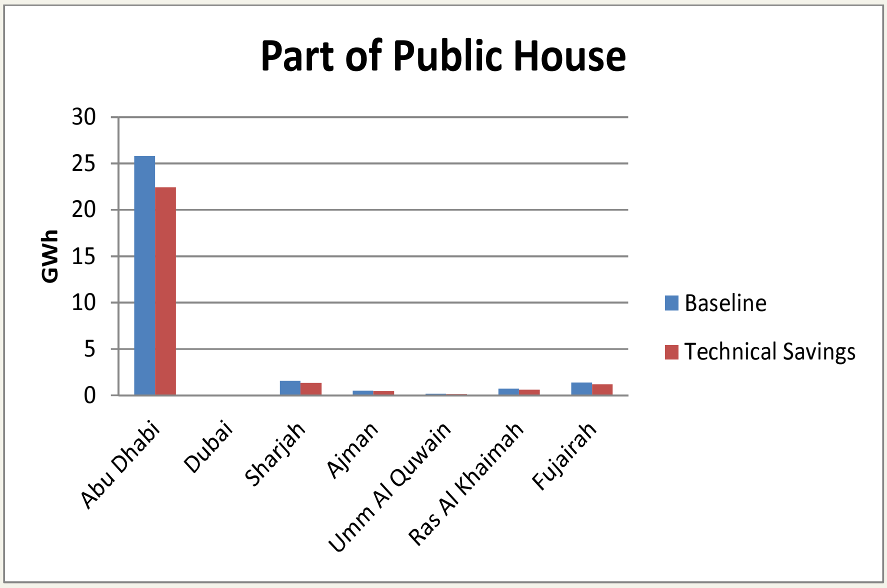
Fujairah
Baseline
Technical Savings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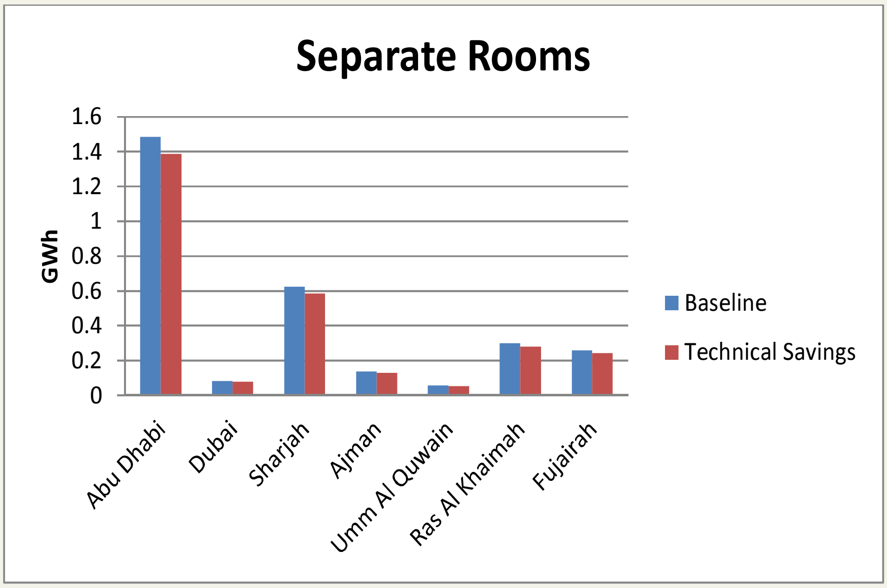
Fujairah
Baseline
Technical Savings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Fujairah
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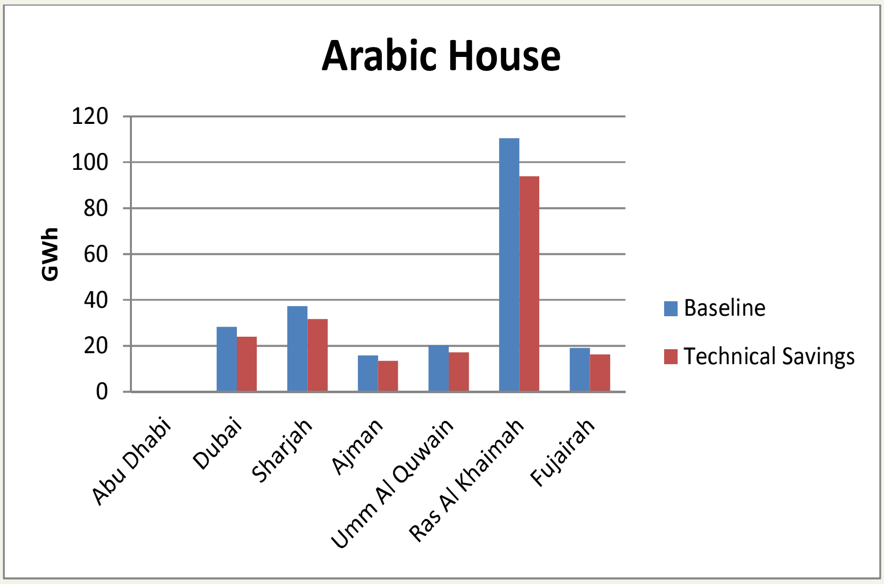
Technical Savings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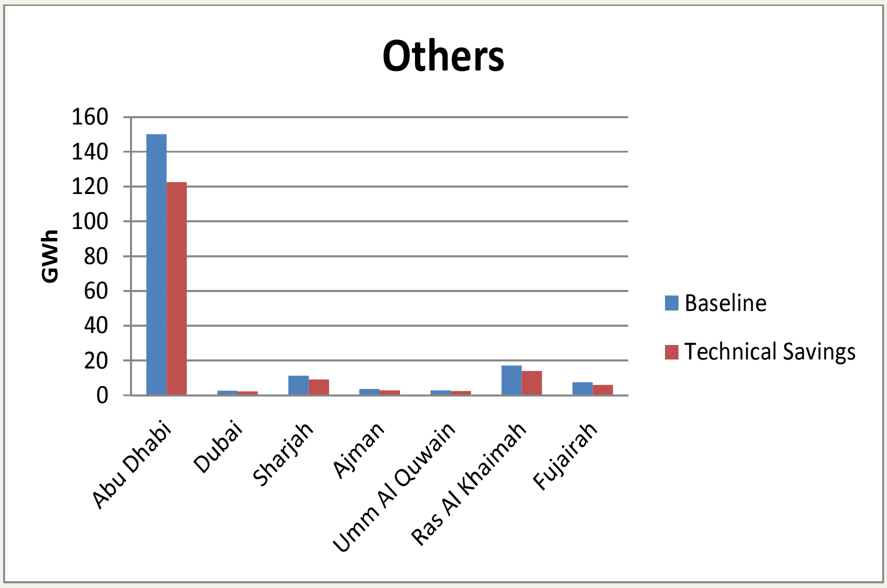
Technical Savings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GWh
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Sharjah
Ajman
Umm Al Quwain
Ras Al Khaimah
Fujairah
Baseline
Technical Savings

Appendix B. Cumulative Annual Social Benefit by Phase-Out Option for Each Emirate (1,000 AED)

Abu Dhabi

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	656	933	66,607	150,005	215,679
Phase 2	712	2,084	72,975	162,137	233,029
Phase 3	720	2,807	73,707	163,733	234,633

Dubai

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	464	505	153,253	-191	152,557
Phase 2	500	1,251	165,026	35	163,810
Phase 3	505	1,757	166,646	39	164,929

Sharjah

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	273	379	51,777	38,465	89,863
Phase 2	296	843	56,567	41,134	96,858
Phase 3	299	1,143	57,130	41,533	97,521

Ajman

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	75	94	21,752	3,123	24,782
Phase 2	81	218	23,472	3,405	26,659
Phase 3	82	301	23,703	3,439	26,841

Umm Al Qiwain

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	40	35	12,820	520	13,305
Phase 2	43	95	13,749	563	14,217
Phase 3	44	139	13,882	569	14,312

Ras Al Khaima

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	255	209	80,611	3,483	83,885
Phase 2	273	587	86,425	3,768	89,607
Phase 3	276	860	87,263	3,806	90,209

Fujeira

	Total Annual Energy Savings (GWh)	Annual increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Phase 1	111	113	34,020	2,666	36,573
Phase 2	120	287	36,593	2,897	39,203
Phase 3	121	407	36,949	2,926	39,468

TECHNICAL MEMORANDUM 3

SUSTAINABILITY IMPACT ASSESSMENT

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LIST OF ABBREVIATIONS

CFL....compact fluorescent light bulb
CH_4....methane
CO_2....carbon dioxide
CO_2eq ....CO_2 equivalents
DSM ....demand-side management
EAD....Environment Agency – AbuDhabi
EEL ....energy-efficient lighting

EF..Ecological Footprint
EFI ....Ecological Footprint Initiative
EPA ....U.S. Environmental Protection Agency
EPR ....extended producer responsibility
ESMA ....Emirates Authority forStandardization and Metrology
EWS-WWF.......................................Emirates Wildlife Society, in association with the World Wide Fund for Nature
GFN...Global Footprint Network
GHG ....greenhouse gas
LCA ....life-cycle assessment
LED ....light-emitting diode lamp
MOEW ....Ministry of Environment and Water
N_2O ....nitrous oxide
NO_x ....nitrogen oxide
PM...particulate matter
RTI ....RTI International
SO_x ....sulfur oxide
UAE...United Arab Emirates
WEEE..Waste Electrical and Electronic

1. Introduction

This report presents the sustainability impact assessment for the development of residential lighting standards for the United Arab Emirates (UAE). The sustainability impact assessment is a snapshot of the current situation and projected future scenarios with respect to lighting in the UAE's residential sector, based on the best-available information. This assessment includes annual estimates for social, environmental, and economic impacts (or savings) that can be attributed to lighting in the sector. The assessment considers impacts that may occur prior to distribution of lighting products to the UAE, during residential use, and after being discarded.

The sustainability impact assessment is one part of an overall study, Development of Lighting Standards for the United Arab Emirates, to establish the basis and recommendations for developing residential lighting standards for the UAE. Section 1.1 explains the background and purpose of this study and includes a description on the tasks to be conducted. The remainder of this section describes the organization of this report and the data requests used to provide information needed for this study.

1.1 Background and Purpose

The UAE has one of the highest per-capita carbon footprints in the world and a growing gap between demand and supply of energy (WWF, 2012). In combination with being a rapidly developing country and having a growing population, the UAE is facing an urgent need to evaluate and establish standards for reducing energy consumption in all sectors, including the residential sector, in a manner that is protective of the environment and of the country's economic and social well-being.

In 2007, the UAE's Ecological Footprint Initiative (EFI) was established through a partnership with the Ministry of Environment and Water (MoEW); the Environment Agency – Abu Dhabi (EAD)[1]; the Emirates Wildlife Society, in association with the World Wide Fund for Nature (EWS-WWF); the Global Footprint Network (GFN); and more recently, the Emirates Authority for Standardization and Metrology (ESMA) to manage its Ecological Footprint (EF) through research, policy, and practice. The knowledge gained from the EFI has benefited the country by creating opportunities for UAE government leaders and residents to move towards sustainable development.

The EFI continues to tackle the country's EF and began a new phase of work in 2012. Included in this scope of work is research to support ESMA in the development of an energy-efficient lighting standard and labeling system for the UAE's residential sector.

The objective of the lighting standard is to reduce energy consumption and carbon emissions while minimizing negative impacts on the UAE economy, environment, and human health. To this end, it is very important to understand the economic, environmental, health, and social implications of the lighting standard for residents and for businesses and governmental agencies.

The residential sector was selected as the focus of this study for several reasons. First, the findings of the EFI—that households account for approximately 57% of energy consumption for the UAE—establish the residential sector as a clear target for improving energy efficiency. In addition, not only does lighting account for a significant percentage of electricity consumption in the residential sector, residential lighting historically has been provided mostly through the use of incandescent lamps, which are the least efficient of the lighting technologies currently in the market. On the other hand, lighting in the commercial, institutional (governmental and public), and industrial sectors is predominantly provided by linear fluorescent lamps, which are among the most efficient of lighting technologies. Compared to the residential sector, the other sectors also tend to be more conscious of energy efficiency and the cost of inefficiency, particularly when there is a financial incentive, as is the case for the commercial and industrial sectors. Furthermore, implementing energy efficiency is easier in the other sectors, where selection of lighting technologies can be made through company or

[1] EAD was represented by its subsidiary body, the Abu Dhabi Global Environmental Data Initiative (AGEDI)

institutional policy decisions, rather than the personal preferences of villa or apartment residents. Finally, if a savings through residential lighting standards can be demonstrated to be material and economical, it stands to reason that this would also be the situation for lighting standards for other sectors.

The decision was made to focus on the carbon component because it accounts for 80% of the country's EF. Depending on location, lighting can account for as much as 20% of the electricity consumed by the residential sector (IEA, 2006); thus, an increased emphasis is being placed on establishing energy-efficient lighting (EEL) and associated policy measures. Lighting also has an impact on cooling load because it can generate heat nearly equal to the number of watts consumed. Cooling is the largest electricity-consuming activity in the UAE.

The UAE has the necessary institutional capacity to also develop such a standard, as evidenced by the labeling system for room air conditioners developed by ESMA for the UAE. With an increased emphasis being put on demand-side management (DSM) measures to address the growing gap between demand and supply of energy in the UAE, EWS-WWF and ESMA are seeking to develop a robust energy-efficiency standard, labeling system, and policy framework for lighting in the UAE's residential sector. This standard can then be expanded to cover public and private sectors as the country gains additional experience and stakeholder support.

1.2 Description of Overall Study

Figure 1 depicts the six tasks that comprise the *Development of Lighting Standards for the United Arab Emirates* study.

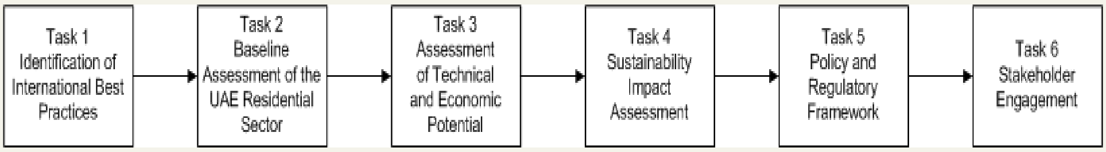

Figure 1. Flow chart for the Development of Lighting Standards for the United Arab Emirates study.

Additional details for each of these tasks are outlined below:

- **Task 1** consists of a review of international best practices. The best practices review will be used to benchmark, identify possible options, and provide a template for the lighting standard developed for the UAE.
- **Task 2** is the baseline assessment of the residential sector in the UAE and includes a profile of the residential lighting sector and an estimate of electricity consumption for residential lighting in the baseline year (see RTI, 2012a).
- **Task 3** consists of an assessment of the technical and economic potential for identified lighting standards (see RTI, 2012b). The goal of this assessment is to ensure that the policy or standard is within an acceptable range of cost and benefit in terms of energy savings potential, carbon savings potential, environmental and health trade-offs, recycling, and financial impacts.
- **Task 4** encompasses a sustainability impact assessment, which is a strategic tool to prevent or minimize adverse impacts to current and future generations. This assessment will cover several areas, including recycling of spent lighting products, mercury waste generation and fate, life-cycle material assessment, cost to consumers, human health effects, public perception, and energy and carbon savings.
- **Task 5** uses the data gathered from the first four tasks (i.e., international best practices, current residential lighting usage, cost-benefit analysis, and environmental impact analysis) to advise stakeholders of policy goals and framework recommendations that will support the

reduction of the UAE's carbon footprint. The outcome of Task 5 includes identification of the activities, capabilities, and regulatory frameworks needed for the successful implementation of lighting standards for the UAE. These will range from educational (e.g., workshops and stakeholder engagement) to enforcement (establishing compliance monitoring, verification, and enforcement programs).

- **Task 6** focuses on stakeholder engagement. This task is a key component of each of the prior tasks because the success of the study can only be assured if key decision makers across the government and the private and residential sectors are involved throughout the standard development process.

1.3 Organization of Report

Section 2 introduces and sets the stage for the sustainability impact assessment that is presented in the remainder of this report. **Section 3** provides an overview of social aspects and potential impacts of lighting technologies. **Section 4** covers the environmentally related impacts of lighting technologies, and **Section 5** discusses economic impacts. **Section 6** presents the overall results for the sustainability impact assessment, as well as recommendations for the UAE.

2. Sustainability Overview

Sustainability, defined in the proceedings of the Brundtland Commission,[2] is achieved by establishing equilibrium between social, environmental, and economic aspects. A sustainability impact assessment aims to identify and evaluate impacts (or benefits) of a particular technology or product that may not be immediately obvious with standard cost or energy savings assessments. For the purposes of this project, the sustainability impact assessment is intended to provide insight into the types of social, environmental, and economic impacts (or savings) that may be associated with adopting newer, more energy-efficient types of lighting relative to the current baseline. The lighting types reviewed here are the same types that have been evaluated in the baseline and economic assessments.

To complete the sustainability impact assessment, we used information from the *Baseline Assessment* (RTI, 2012a) and *Assessment of Technical, Economic and Achievable Potential* (RTI, 2012b), as well as secondary sources of data and information, including existing life-cycle assessment (LCA) reports, international agency reports on lighting policies, and academic, industry, and independent research on lighting technologies. We conducted a literature review and an assessment of the social, environmental, and economic impacts of lighting options for the residential sector in the UAE using available data and estimates. The results of the assessment are reported here in three sections:

- ***Social Impacts of Lighting Technologies.*** This section reviews the social barriers and opportunities associated with each lighting technology. For example, if a particular lighting technology does not generate a comfortable color when illuminated or flickers during use, individuals may be reluctant to convert to the technology regardless of the energy savings or other benefits associated with lighting conversion. These issues can be critical to the success of lighting conversion programs and must be understood fully to ensure that the range of lighting options that meet residential lighting needs and account for public opinion are included.
- ***Environmental Impacts of Lighting Technologies.*** This section presents an assessment of the potential energy, health, and environmental impacts associated with the different life-cycle stages for each technology and a summary of the results. An LCA can help identify indirect or transferred effects of products or technologies by investigating the upstream and downstream energy and material use impacts. Environmental impacts reported include greenhouse gas

[2] http://www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html

(GHG) emissions; sulfur oxide (SO_x), and nitrogen oxide (NO_x) air emissions; particulate matter (PM); and hazardous and non-hazardous waste potential.

- ***Economic Impacts of Lighting Technologies.*** The direct and indirect economic effects of phasing in EEL are detailed in the *Assessment of Technical, Economic and Achievable Potential* (RTI, 2012b). In this report, we summarize those results and addresses additional potential indirect economic impacts that lighting technology standards may have. For example, the disposal of certain types of fluorescent lamps may result in the need to discard the lamp as hazardous material or to establish preventative measures to mitigate any environmental or health impacts the mercury might cause.

This sustainability impact assessment investigates the various social, environmental, and economic benefits and costs of the lighting technologies currently employed and projected for use in the UAE. The assessment considers impacts that may occur prior to distribution to UAE, during residential use, and after being discarded. Although the most significant social, environmental, and economic impacts of each technology were found to occur during the use phase and were highly correlated with energy efficiency, other issues such as accumulation of mercury waste are also discussed.

3. Social Impacts of Lighting Technologies

Public perception and individual lighting preferences play a large role in whether a lighting technology will be accepted and ultimately used in the residential sector. As such, the factors that determine residential lighting preference must be considered when making policy decisions regarding lighting. For example, in the European Union, United States and other countries, bans (or proposed bans) on incandescent bulbs has created significant backlash[3]. Many individuals prefer the light from incandescent bulbs, do not like government dictating consumer purchasing, and are not certain that current alternatives (namely compact fluorescent light bulb [CFLs]) provide an environmentally better option.

In order to gain a better understanding of the public perceptions of EEL technologies, RTI reviewed independent, academic, and industry references regarding social aspects for each lighting technology. **Table 1** summarizes the advantages and disadvantages of each lighting technology found in the literature.

Table 1. Summary of Social Advantages and Disadvantages of Each Lighting Technology (Navigant, 2009; VITO, 2009).

Advantages	Disadvantages
Incandescent	
▪ Inexpensive to purchase ▪ Excellent color rendering ▪ Easily dimmed ▪ Full lighting level immediately when switched on	▪ Low efficacy: ~ 8-17 lm/Watt ▪ Short lifetime: 1,000 hours ▪ Higher costs associated with powering ▪ High operating temperature
Halogens	
▪ Inexpensive to purchase compared to CFLs, LEDs ▪ Excellent color rendering ▪ Easily dimmed	▪ Low efficacy: ~ 14-18 lm/Watt ▪ Short lifetime: 2,000 hours ▪ Higher costs associated with powering ▪ High operating temperature – can represent a fire hazard[4]

(continued)

[3] http://www.popularmechanics.co.za/home-how-to/diy-news-features/the-light-bulb-wars/
[4] http://www.cpsc.gov/CPSCPUB/PREREL/PRHTML96/96174.html

Table 1. Summary of Social Advantages and Disadvantages of Each Lighting Technology (Navigant, 2009; VITO, 2009) (continued).

Advantages	Disadvantages
LFL	
▪ Inexpensive to power ▪ Very good color rendering ▪ High efficacy: ~ 55-90 lm/Watt ▪ Long lifetime: 20,000 hours	▪ Ballast gear required ▪ Lifetime may be shortened when switched on and off frequently ▪ Dimming requires special ballast ▪ Contains mercury (breakage and disposal concerns) ▪ Lighting may flicker
CFL	
▪ Inexpensive to power ▪ High efficacy: ~ 44-58 lm/Watt ▪ Long lifetime: 8,500 hours ▪ Poor color rendering	▪ Moderately expensive to purchase ▪ Lifetime may be shortened when switched on and off frequently ▪ Dimming requires special ballast ▪ Contains mercury (breakage and disposal concerns)
LED	
▪ Inexpensive to power ▪ High efficacy: ~ 52 lm/Watt ▪ Long lifetime: 25,000 hours ▪ Good color rendering in newer products ▪ Easily dimmed	▪ Expensive to purchase (currently the highest priced) ▪ Technology is not fully mature, lifetime and visual quality of lamps may not be ideal or consistent. ▪ Lighting choice is limited – directional lighting is most common type currently available.

Table 1 illustrates that the main perceived advantages of incandescent lamps, purchasing cost, color rendering, and immediate full lighting level are countered with disadvantages such as low efficiency, higher costs to supply electricity, and shorter lifetimes. Incandescent lights typically emit “warmer” light than CFL and LED lights, which usually emit white, “colder” light. Some studies indicate that warmer color rendering is preferred in residential lighting (Navigant, 2009). However, informal communications suggest that colder, brighter light may be preferred in very sunny, bright and warm regions such as the UAE. One notable disadvantage of incandescent lighting in warmer climates is also the higher operating temperature. These lamps may not only cost more to power, but they can increase space cooling because of their high operating temperatures (Lawrence Berkeley National Laboratory, 1998).

Halogen lamps have a slightly longer lifetime and higher average efficacy when compared to incandescent lamps, but are still relatively energy-inefficient when compared to fluorescent lighting and LED technologies. However, halogen lamps cost less to purchase than these higher-efficiency products and are easily dimmed. Like incandescent lamp use, halogen lamp use generates an increased cooling cost burden due to high operating temperatures. The operating temperatures of halogen lamps can be so high that the U.S. Consumer Product Safety Commission issued a warning to consumers that halogen lamps could start fires if they come into contact with curtains, clothes, or other flammable material (U.S. Consumer Product Safety Commission, 1996).

CFL lamps exhibit better efficiency and duration, as well as lower temperature and operating costs than incandescent and halogen lamps. However, these lamps cost more, many consumers do not like their bright white light (particularly those in temperate climates), and they require supplemental components to be dimmable. Additionally, CFLs require mercury vapor to function, which may represent a public health hazard if broken (U.S. EPA, 2012b). The CFL lifetimes may also be shortened by frequent switching cycles (such as in a highly trafficked bathroom with occupancy sensors), adding to their costs and discard volumes over time (Navigant, 2009).

High-quality light-emitting diode lamps (LEDs) have been demonstrated to also exhibit high-efficiency, long duration, lower operating costs, and cooler operating temperatures. Disadvantages include high purchase costs and the relatively new existence of the technology (i.e., the technology may not have met its full potential for duration, illuminance, or other features important to LED consumers). It is important to note that the quality of the LED lamps should also be assured using international standards or certifications, since poor-quality LEDs may lose illuminance, cease to function, flicker, and ultimately lose public trust (U.S. Department of Energy, 2012). Furthermore, general-use LED lighting is less commonly available than LEDs used for specific purposes, such as under-cabinet lighting and solar garden lamps (Navigant, 2009). In short, the technology must mature and become more available for the advantages of LEDs to be fully realized.

Several studies indicate that the most consistently and frequently mentioned barrier to general consumer acceptance of high-efficiency lighting technologies is retail cost (Stall-Meadows and Herbert, 2011; Martinot and Borg, 1998). Currently, CFL and LFL lamps are more expensive to purchase than incandescent lamps, and (being the newest technology) LEDs are much more expensive than the other technologies. It was observed that although the upfront cost of CFLs and LEDs are considered cost-prohibitive by many consumers, the willingness to purchase may occur if lifetime costs (e.g., decreased cost of electricity to power CFLs and LEDs when compared to incandescent lighting) are considered alongside upfront costs (Stall-Meadows and Herbert, 2011). In the UAE context, where many goods, such as residential electricity, the price elasticity of demand, and social acceptance would likely vary by UAE demographic context, different income groups, etc. Some groups may be more accepting of a standard that phases in more costly higher-efficiency goods than others. However, in RTI's *Assessment of Technical, Economic and Achievable Potential,* conducted as part of the overall project (RTI, 2012b), it was found that all demographic groups would benefit economically from EEL.

Research also indicates that while interest in sustainable lighting is increasing as knowledge about the products increases, LEDs especially are currently considered cost-prohibitive (Stall-Meadows and Herbert, 2011). Identifying ways to defray the costs of efficient lighting technologies while encouraging UAE consumers to consider lifetime costs alongside initial costs—whether through economic, legal, or other methods—will be essential for increasing the residential market share of sustainable lighting products in the UAE (Stall-Meadows and Herbert, 2011).

In addition to cost, lighting quality has been cited as a potential adoption barrier for LED and CFL lamps. Issues include illuminance or brightness, flickering, and warm-up time (i.e., the delay between activating the lamp and when full illuminance is observed). Current high-efficiency CFL and LED lamps have rectified or greatly reduced these issues; however, more surveys must be conducted to determine whether the perceived barriers to these technologies have been sufficiently removed.

Furthermore, because consumers have become used to the characteristics of incandescent lighting products over the past century, it may simply take time for public perceptions to shift regardless of whether lighting quality barriers have been surmounted. The advantages and disadvantages of each technology will need to be weighed and re-weighed as CFLs and LEDs become less expensive and the technologies fully mature. It is anticipated that as each technology becomes more common in the market and more policy restrictions are placed on incandescent lamps, the barriers and public perceptions will shift to match the policies.

In the UAE context, existing examples in other countries (United States, European Union, Australia, and elsewhere) can provide good learning opportunities to address a number of social aspects and acceptance of high-efficiency lighting. Some activities for the UAE to consider in the setting of a lighting standard might include the following:

- Verifying CFL, LED, and other lamp performance as compared to incandescent lamps
- Implementing a public outreach campaign to educate residents about the benefits of EEL
- Phasing in any ban on incandescent bulbs to allow time for residents to adjust
- Putting in place effective recycling systems to address mercury-containing bulbs (e.g., CFLs, LFLs).

4. Environmental Impacts of Lighting Technologies

RTI conducted a literature review and prepared an assessment of the energy and environmental impacts associated with lighting technologies. The environmental impacts are analyzed using an LCA framework, which provides a technique for assessing the environmental aspects of a system through each life-cycle phase: raw materials acquisition, production, distribution use, and disposal. **Figure 2** illustrates the key phases of the LCA process for lighting technologies, which encourages planners and decision makers to consider the environmental aspects of lighting technologies, including activities that occur outside of the traditional framework, such as amount of waste generated or potential environmental impacts of technologies.

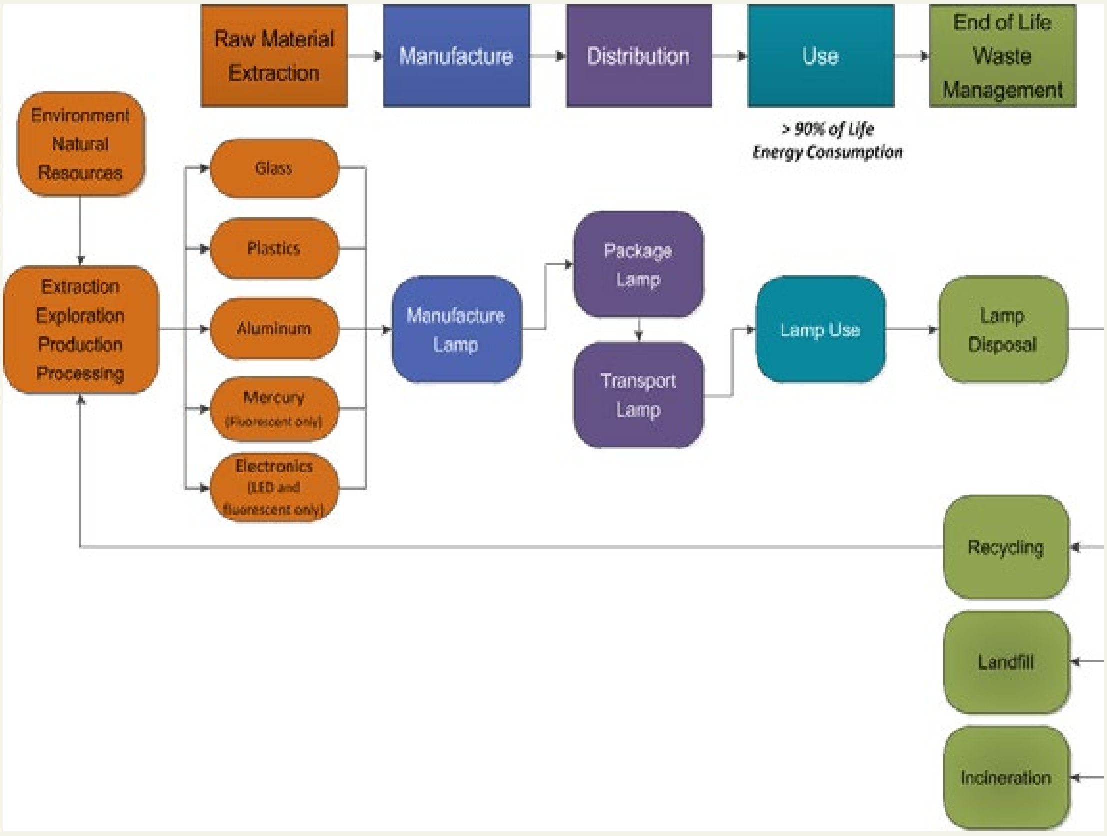

Figure 2. Life-cycle processes and stages for lighting technology.

The objective of an LCA is to identify and compare different products or systems to determine where they have their greatest environmental impact. In this respect, LCA can be a valuable tool to ensure that a given technology creates actual environmental improvements rather than just transfers environmental burdens from one life-cycle stage to another or from one environmental media to another. This analysis is also useful for screening systems to identify the key drivers behind their environmental performance.

RTI reviewed LCA information from several recent (2000 to date) sources and summarized the key aspects in **Table 2**.

Table 2. Summary of Recent Studies

Publication: Title, Author, Year	Lamps Evaluated	Region	End-of-Life Management	Functional Units Used	Energy Grid Mix	Impact Categories Reported	Overall Findings
Environmental Impacts of Lighting Technologies – Life Cycle Assessment and Sensitivity Analysis **Welz et al., 2011**	Tungsten; Halogen; Fluorescent; Compact Fluorescent	Switzerland (Europe)	Recycling and incineration. This study stated that halogen, fluorescent, and CFLs benefit through recycling	1 hour of lighting	Two grid mixes: Swiss- Mix (nuclear, 39.9%; hydro, 53.7%; Fossil-thermal, 1.8%; Other renewable, 0.1%; Others, 4.4%); European UCTE-Mix (nuclear, 31.6%; hydro, 11.4%; fossil-thermal, 51.1%; Others, 5.8%); Hydroelectricity- mix; Wind/solar- mix.	Cumulative Energy Demand; Global Warming Potential; Eco-Indicator ‘99	In regards to environmental impacts, this study concluded that substituting CFLs in place of Tungsten Lamps is the best option. Also, in the study’s conclusion, it was reported that the quality of the CFL has no relevant effect on overall environmental impacts.
Life-cycle Assessment of Energy and Environmental Impacts of LED Lighting Products **Navigant, 2012**	Incandescent; Compact Fluorescent; LED Lamps	United States	The assumed management techniques in this study are as follows: CFLs are recycled; LED procedures are to throw out, but the study stated that reusing or recycling could greatly reduce impacts	20 million lumen-hours	Not specified in this report	Global Warming Potential; Water Quality; Toxicity; Air Pollution	This study concluded that LEDs and CFLs are similar in energy consumption, while incandescents consume about four times more energy than the amount consumed by CFLs and LEDs. However, the energy savings from the CFLs and LEDs are likely less than the halogen lamp. LED energy use will decrease by about 1/2 if the lamps meet their performance goals.

(continued)

Table 2. Summary of Recent Studies (continued)

Publication: Title, Author, Year	Lamps Evaluated	Region	End-of-Life Management	Functional Units Used	Energy Grid Mix	Impact Categories Reported	Overall Findings
Life-cycle Assessment of Ultra-Efficient Lamps **Navigant, 2009**	LEDs; Ceramic Metal Halide; Linear Fluorescent; Compact Fluorescent; Incandescent Lamps	United Kingdom	In this study, it was assumed that 20% of the lamps would be recycled. The remaining 80% were assumed to be disposed in landfills.	Megalumen-hours	UK Grid	Global Warming; Acidification; Photochemical Ozone Creation; Ozone Depletion; Toxicity; Ecotoxicity; Eutrophication; Land Use; Ecosystem Damage; Resource Depletion; Waste Landfilled	In this study, incandescent lamps produced almost six times more life-cycle CO_2 emissions than fluorescent lamps. The study concluded that the CFL is similar to the LED except the LED had slightly higher impacts due to the aluminum content. Incandescents were found to have the highest impacts due to high-energy consumption. From the data in 2009, the best lamp technology, according to this study, was the linear fluorescent T5 system.
Life Cycle Assessment of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps **OSRAM, 2009**	Conventional; CFL; LED lamp	Germany (Europe)	This study stated that CFLs and LEDs are supposed to be recycled professionally; most lamps are thrown away by consumers. In this study, recycling and incineration are main forms of waste treatment for LEDs and CFLs.	kWh	Europe (nuclear, coal and renewables); Germany (nuclear, coal, and renewables); Malaysia (natural gas); China (coal)	Global Warming Potential; Acidification Potential; Eutrophication Potential; Photochemical Ozone Creation Potential; Human Toxicity Potential; Abiotic Depletion Potential	According to this study, the use phase is the most significant phase for impact. Incandescents are the least efficient, while CFLs and LEDs are competitive. In terms of environmental impacts, LEDs were found to be environmentally preferable to CFLs.

(continued)

Table 2. Summary of Recent Studies (continued)

Publication: Title, Author, Year	Lamps Evaluated	Region	End-of-Life Management	Functional Units Used	Energy Grid Mix	Impact Categories Reported	Overall Findings
Domestic Lighting **VITO, 2009**	Incandescent; Halogen; CFL; LED	European Union	CFLs were assumed to be recycled. (Some countries exported them if there was no domestic recycling facility.) Ninety percent of mercury was assumed to emit into the atmosphere after disposal. Incandescent and halogen lamps are assumed to go to a landfill.	Per lumen per hour	European UCTE mix	Gross Energy Requirement; Global Warming Potential	This study concluded that CFLs appear to have the lowest environmental impacts due to their low-energy consumption, even though they emit mercury at the end-of-life stage. Incandescent lamps were found to have the highest impacts, according to this study, due to high-energy consumption during the use phase. The study mentions there are improvements that can be made to CFLs, at the risk of raising cost, to reduce the amount of mercury in the lamp.
Comparison of Life-Cycle Analyses of Compact Fluorescent and Incandescent Lamps Based on Rated Life of Compact Fluorescent Lamp **Rocky Mountain Institute, 2008**	Incandescent; CFL	United States	This study assumes that all lamps are disposed at a landfill	10,000 hours with 1,600 lumens of light	US average Electricity Mix (Coal 49.61%, Nuclear 19.28%, Gas 18.77%, Hydro 6.5%, Oil 3.03%, Other 2.81%)	Global Warming Potential; Mercury Pollution; Lead and Arsenic Pollution	This study reports that CFLs show fewer emissions in the use phase than incandescent bulbs. However, consumers need to be aware of safe disposal methods for CFLs due to the contained mercury. This study also stated that CFLs are most efficient when left on for long periods of time because they have longer lamp life, faster payback, and fewer GHG emissions than incandescent bulbs.

(continued)

Table 2. Summary of Recent Studies (continued)

Publication: Title, Author, Year	Lamps Evaluated	Region	End-of-Life Management	Functional Units Used	Energy Grid Mix	Impact Categories Reported	Overall Findings
Confidence in Quality: Harmonization of CFLs to Help Asia Address Climate Change **USAID, 2007**	CFL	Asia	Recycling of CFLs is assumed in this study	Lumen per watt	Not Specified	GHG Emissions, Waste Production	This study concluded that CFLs are better than incandescent bulbs, but low-quality CFLs are not as efficient as higher-quality CFLs. The U.S. Agency for International Development (USAID) recommended that quality standards for CFLs be developed to reduce waste and GHG emissions.
Regional Report on Efficient Lighting in the Middle East and North Africa **Gelil, 2011**	Incandescent; CFL	Middle East, Northern Africa	This study assumes that CFLs are disposed of in landfills, and the study mentioned that if CFLs were recycled at collection points, the mercury would be properly handled and not released into the environment.	Terawatt-hour	Mainly coal and some natural gas	Energy Consumption; Mercury Pollution; GHG Reduction	This study concluded that phasing out from Incandescent lighting into CFLs would greatly reduce this region's electricity consumption and GHG emissions. However, the author thought there should be a quality standard put into place to eliminate low-quality, high-energy consuming, high mercury content CFLs.

According to the studies list in Table 2, the most significant life cycle is the use phase, which was reported to account for 90–99% of the total life-cycle energy consumption (i.e., total energy used to manufacture, illuminate, and discard lamps). Furthermore, these studies highlight that the energy consumed during the use phases of incandescent lamps is significantly greater than CFLs, LFLs, and LEDs. Our review indicates that although there are differences in form and function between LEDs, LFLs, and CFLs, employing these technologies in residential lighting situations was found to be roughly four times more energy efficient than the use of incandescent lamps and over twice as energy efficient as using halogen lamps, respectively. **Figure 3** illustrates the energy demand over the life cycle of each of the lamp technologies.

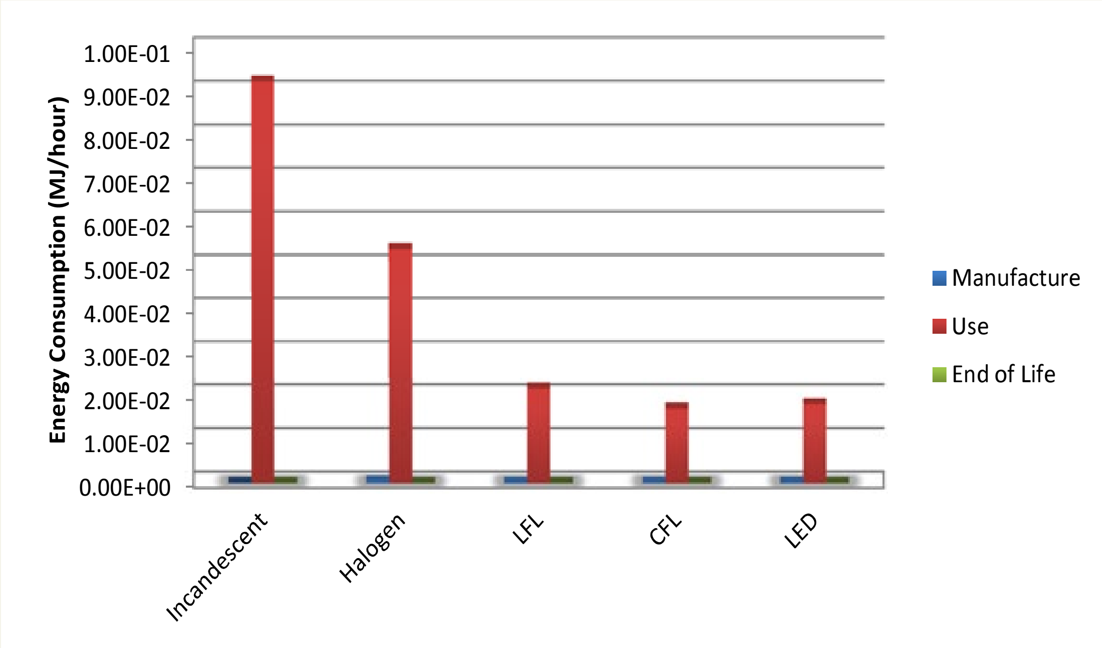

Figure 3. Energy consumption across life-cycle phases for lighting technologies (Welz et al., 2011; Navigant, 2009[5]).

Much of the environmental impacts associated with lighting technologies are due to the energy used during the use phase because of the significant amount of energy used during this phase and because of energy types employed to power most electricity grids, like natural gas, coal, and other fossil fuels (Welz et al., 2011). For example, natural gas combustion can emit gases that contribute to climate change, acid rain, smog, and other impacts. Therefore, the environmental impacts of all lighting products can be significantly reduced by increasing the contribution of energy sources with lower environmental impacts, such as solar, wind, and hydro power (Welz et al., 2011).

Manufacturing and end-of-life phases also use energy and therefore have similar energy-related environmental impacts associated with them. In addition, these phases may have other issues such as health hazards, ecological toxicity, and landfill volume (VITO, 2009). The environmental impacts associated with each lighting life-cycle phase are discussed in the sections below.

In addition to these impacts, there are other potential environmental impacts that are more difficult to quantify at this time due to the lack of data and information, such as the following:

- **Rare earth materials.** Many of the lighting systems utilize rare earth materials in their manufacturing. Demand for rare earth materials has increased greatly as these materials are

[5] Incandescent, halogen, LFL, and CFL data illustrated in Figure 3 is based on Welz et al., 2011, because this study contained the most complete energy estimate information out of all studies. LED data has been extrapolated from Welz et al. CFL energy estimates using the ratio of LED to CFL global warming potentials for each life-cycle phase found in Navigant, 2009.

used in a multitude of electrics (such as cell phones and batteries). They are also components of EEL. Mercury for example is used in CFLs and LFLs. Much of the mercury in used in CFL and LFL production is likely sourced from China where these products are predominately manufactured. Other key countries that mine mercury and provide much of the global supply are Spain, Kyrgyzstan and Algeria (Environment Directorate-General of the Commission of the European Communities, 2004). Increased demands for mercury and other rare earth materials could have cost implications, especially as rare earths form the backbone for other low carbon technologies.

- **Indirect biodiversity impacts.** The extraction industry for rare earth materials can result in impacts to ecosystems and biodiversity. It is difficult to determine what portion of these impacts could be attributable to EEL. In addition, the reduction in the consumption of electrical energy achieved by implementing standards that require EEL use will reduce emissions from power production, which can have a positive impact on ecosystem health and biodiversity in the region where the power is produced.
- **Water consumption impacts.** Large quantities of water are often used in mining operations as well as in the power sector. With the implementation of EEL standards, water consumption impacts could be exacerbated on the materials extraction stage but reduced on the power production stage of the life cycle.

4.1 Manufacturing Stage Impacts

LCA-type studies for alternative lighting technologies (as shown in Table 2, for example) generally indicate that the environmental impacts of manufacturing stage of lighting technologies are greatly outweighed by impacts realized in the use phase due to the energy used for illumination. However, it is important to note that these LCAs have largely been developed using North American and European manufacturing estimates. Manufacturing of CFLs and other mercury-containing bulbs can represent a potential risk if the manufacturing operators do not take precautions. For example, recent articles from China have highlighted the issue. One focal article[6] was posted by Michael Sheridan from Foshan, a city in southeastern China. As part of the article, Chinese workers were interviewed anonymously and gave detailed accounts of medical tests. One test found 68 out of 72 workers required hospitalization as a result of mercury poisoning. In Jinzhou, Central China, 121 out of 123 employees had excessive mercury levels, up to 150 times the accepted standard. The main exposure method of mercury was stated to be inhaled toxic dust and fumes from cauldrons used to extract the mercury, without adequate protective clothing or masks.

The Sheridan article highlights the need for best practices across all stages of the lighting product life cycle. Additionally, it illustrates that caution must be taken to ensure that environmental burdens are truly being alleviated when considering a new initiative rather than being transferred from one life-cycle stage to another. Although this information has not been captured in current LCAs, it is likely that these types of impacts would greatly increase the environmental impact of the manufacturing stage even though use-phase environmental impacts would be reduced.

4.2 Use Stage Impacts

During the use phase, impacts are primarily realized through the energy consumed to illuminate each of the lighting technologies. As indicated in the previous sections, the majority of energy and environmental impacts from lighting technologies are due to the use phase. Additionally, the environmental impacts are highly dependent on the electrical grid mix, which powers the lighting technologies.

RTI assessed the energy savings and reduction in environmental impacts associated with converting UAE’s current lighting infrastructure to include more efficient lamps in a series of three phases, as defined in the RTI (2012b) *Assessment of Technical, Economic and Achievable Potential*

[6] http://www.chinadaily.com.cn/opinion/2010-03/11/content_9571162.htm

memorandum. Given the population of lamps presented in the *Baseline Assessment* (RTI, 2012a), families of lamp technologies are targeted for replacement, and this defines the technical potential. The *Assessment of Technical, Economic and Achievable Potential* memorandum lists the baseline lamp types and the associated EEL-type replacement, where applicable. The replacement model is summarized as follows:

- Incandescent phase-out estimates represent the conversion of all existing incandescent lamps to high-efficiency CFL or LED lamps
- Halogen phase-out estimates represent the conversion of all halogen lamps to high-efficiency CFL or LED lamps
- Low-efficiency CFL phase-out- estimates represent the conversion of all low-efficiency CFL lamps to high-efficiency CFL or LED lamps.

The replacement model assumes that all upgrades switch to high quality CFL or LED lamps. In general, CFLs and LEDs have similar performance in terms of energy reduction potential. There are tradeoffs associated with each lamp. CFLs are significantly less costly to purchase. The high purchase cost of LEDs has limited market penetration in most countries. However, LEDs have longer life expectancies compared to CFLs, and do not contain mercury.

The *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b) provides a detailed listing of the baseline lamp types and the associated EEL-type replacement, where applicable. Energy savings from switching to EEL are estimated for incandescent, halogen, and low-efficiency CFL lamps. The baseline assumes that 15% of CFLs are sub-standard (lower luminous efficacy and shorter life expectancy [RTI, 2012a]) and the removal of these low-efficiency CFLs is part of the technical potential. For high-efficiency CFLs, LFLs, and LEDs currently in use, it is assumed that there are no upgrade possibilities included in the analysis.

4.2.1 Energy Consumption

Table 3 presents the potential direct *and* indirect (cooling bonus) energy savings for the replacement scenarios compared to the baseline assessment. For the indirect cooling bonus, lighting systems convert only a fraction of their electrical input into useful light output. A large share of the energy is released directly as heat into the space. Within lamp type, the amount of heat released is roughly proportional to the wattage of the lamp. Any upgrade of the lighting system will thus reduce the amount of heat that must be removed by the air cooling system. This results in air cooling energy savings during the operation of the building. The cooling savings is calculated as 28 percent of the direct lamp energy saving. Specific assumptions used to calculate both the direct and indirect energy savings results are discussed in further detail in the *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b).

Table 3. Potential Direct and Indirect Energy Savings from Lamp Replacement in Gigawatt-hours (GWh).

	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Qiwain	Ras Al Khaima	Fujeira	Total
Incandescent Phase-out	657	465	274	75	40	255	111	1878
Halogen Phase-out	55	36	22	6	3	18	8	148
Low-efficiency CFL Phase-out	7	5	3	1	0	3	1	20
Total	719	506	299	82	43	276	120	2046
Percent	35.1%	24.7%	14.6%	4.0%	2.1%	13.5%	5.9%	100.0%

This aggregate (direct plus indirect) energy savings was estimated to be 2,046 GWh (RTI, 2012b). From the baseline assessment, it was estimated that 2,442 GWh are consumed annually for residential lighting in the UAE. Therefore, the total electricity savings from the lamp replacement scenarios would be approximately 84 percent of the total baseline residential lighting electricity consumption. A total of approximately 70,000 GWh of electricity is consumed annually in the UAE (2008 figures). Therefore, the total electrical energy savings per the lamp-replacement scenarios would represent approximately 3.5% of the total electricity consumed in the UAE.

The energy savings results are also presented in **Figure 4**. As illustrated, the most significant savings are realized through phasing out incandescent lamps and replacing them with high-efficiency CFL lamps. Phasing out incandescent lamps would have the largest energy savings impact in Abu Dhabi and Dubai, followed by Sharjah and Ras Al Khaima, because of the greater numbers of residential lamps in these Emirates.

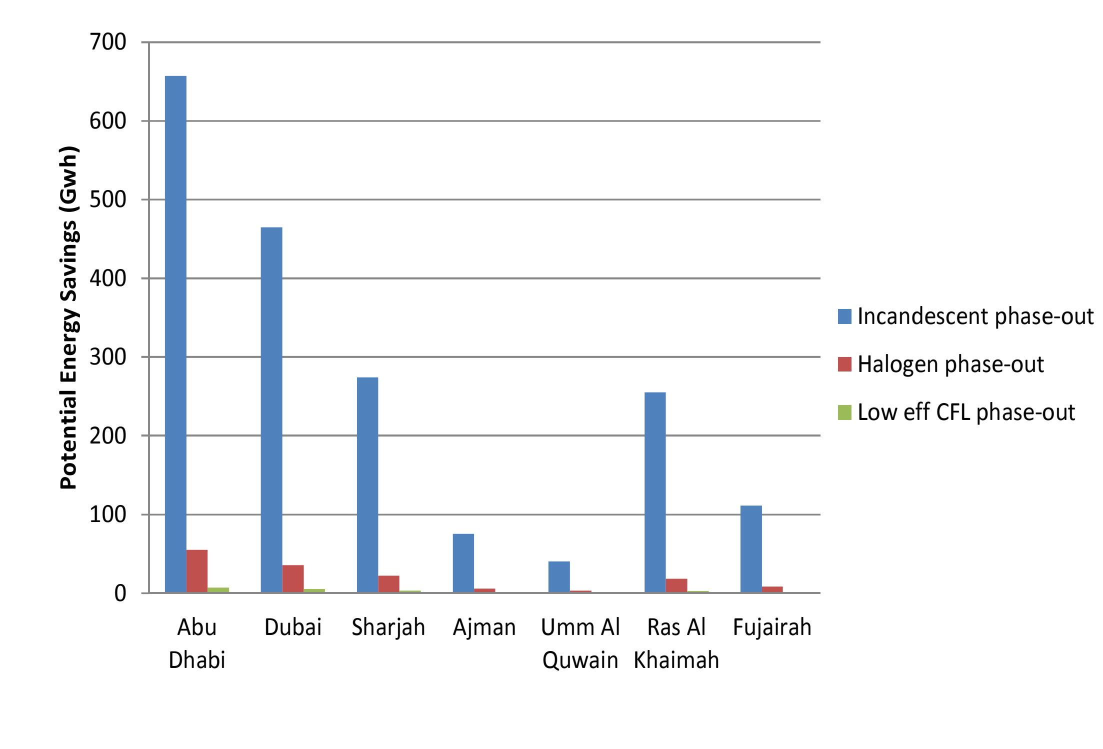

Figure 4. Potential energy savings from lamp replacement (GWh/year).

4.2.2 Emissions

RTI also estimated the impact of each scenario's energy savings on climate change and key atmospheric pollutants. The assumptions for this analysis include the following:

- The primary energy source used to generate utility grid electricity in UAE is natural gas (International Energy Agency, 2011).
- Methane (CH_4), SO_x, NO_x, and PM data for natural gas extraction and combustion were taken from the National Renewable Energy Laboratory (NREL) North American life-cycle inventory database.[7]
- Carbon dioxide (CO_2) emissions are provided by Masdar Institute. Because water desalination and electricity plants are co-located and both generate CO_2 in UAE, the CO_2 emission estimate has been partitioned to represent only those emissions due to electricity generation (Kennedy et al., 2011).

[7] http://www.nrel.gov/lci/

- SO_x, NO_x, and PM emissions data represent each scenario's impact on air quality in UAE (SCAD, 2012).

Using the energy savings potential assessed in *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b) and natural gas emissions estimates obtained from Kennedy et al (2011) and NREL (2012), the potential GHG, SO_x, NO_x, and PM emissions reductions were estimated. **Table 4** presents the emissions data used in calculating the emissions savings related to each scenario.

Table 4. Fuel-related Emissions for Natural Gas Usage

Pollutant	Emissions (Kg/Gwh Elect.)
Particulate Matter (Total)	21.74[a]
Carbon Dioxide	420,000.00[b]
Methane	1,848.36[a]
Nitrogen Oxides	2,480.69[a]
Sulfur Oxides	9,585.52[a]
Nitrous Oxide	0.06[a]

[a] NREL, 2012
[b] Kennedy et al., 2011

The energy savings displayed in Table 3 were then multiplied by the pollutant emissions from natural gas in Table 4 to yield emissions estimates for each scenario. For GHG estimates, standard global warming potentials of 1, 21, and 310 were applied to CO_2, CH_4, and N_2O, respectively in order to present the data in terms of CO_2 equivalents (CO_2.eq) (United Nations Framework Convention on Climate Change, 2012). **Table 5** and **Figure 5** present the estimated GHG emissions reduction for each scenario.

Table 5. Potential GHG Emissions Reduction from Lamp Replacement in tonnes CO_2.eq per year.

	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Incandescent Phase-out	301,553	213,138	125,699	34,642	18,561	117,009	51,068	861,669
Halogen Phase-out	25,212	16,367	10,168	2,729	1,328	8,330	3,827	67,960
Low-efficiency CFL Phase-Out	3,233	2,258	1,337	367	193	1,217	535	9,139
Total	329,998	231,763	137,204	37,738	20,082	126,556	55,430	938,768
Percent	35.2%	24.7%	14.6%	4.0%	2.1%	13.5%	5.9%	100.0%

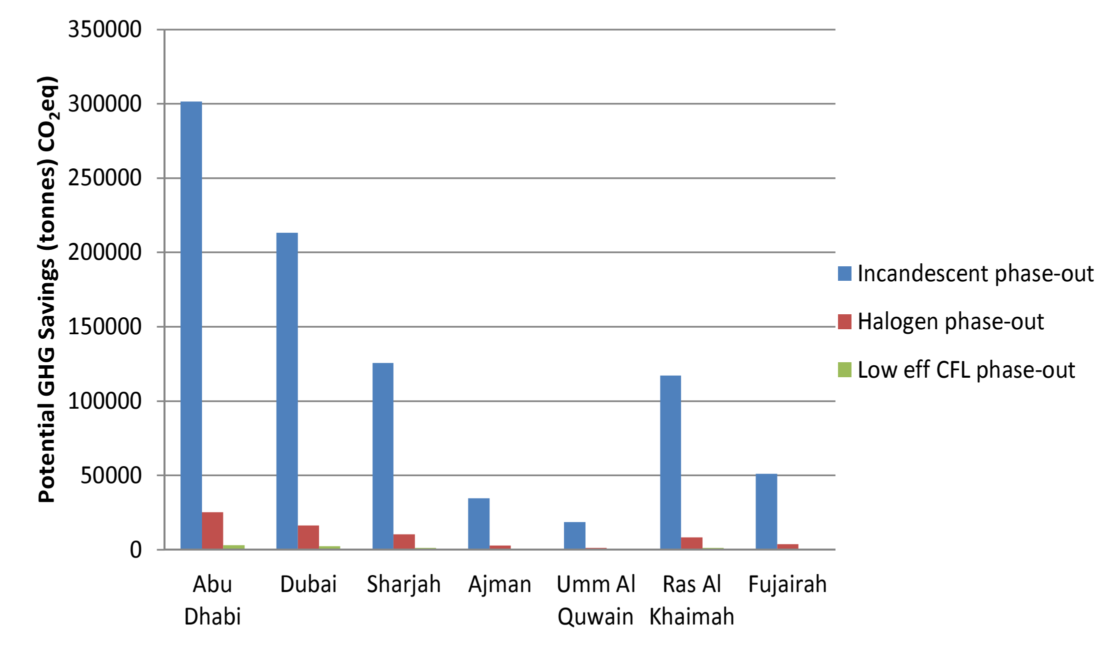

Figure 5. Potential GHG emission savings from lamp replacement (tonnes/year).

The annual GHG savings potential associated with all three phase-outs is almost 940,000 tonnes of CO_2-eq emissions. This savings is equivalent to taking over 165,000 cars off of the road each year (U.S. EPA, 2012a). Total UAE CO_2 emissions were estimated to be 25 tonnes per capita in 2008 by the World Bank[8]. This per capita factor equates to approximately 150 million tonnes of CO_2 emissions using World Bank population data for 2008. However, this does represent low hanging fruit, and over a longer time period (say 10 years), the total accumulated CO_2 emissions savings would be relevant.

The results indicate that the elimination of nearly all incandescent lamps in residential homes would have the most beneficial impact on climate change; however, all three phases contribute to a reduction in global warming potential. As expected, based on the high levels of energy consumption in Abu Dhabi and Dubai, implementation of high-efficiency lamp scenarios in these Emirates would have the most significant impact on UAE climate-change indicators.

Use-phase contributions to two other key atmospheric pollutants (NO_x and SO_x) were also estimated. These pollutants contribute to acidic atmospheric conditions and acid rain and are precursors to other air quality issues, such as smog and particulate matter (EEA, 2011). **Table 6** and **Figure 6** present the potential NO_x savings, and **Table 7** and **Figure 7** present the potential SO_x savings for each scenario annually. Results are presented in tonnes.

[8] http://data.worldbank.org/indicator

Table 6. Potential NO_x Emissions Reduction from Lamp Replacement (tonnes/year).

	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Incandescent Phase-out	1630	1152	680	187	100	633	276	4659
Halogen Phase-out	136	88	55	15	7	45	21	367
Low-efficiency CFL Phase-out	17	12	7	2	1	7	3	49
Total	1783	1252	742	204	108	685	300	5075
Percent	35.1%	24.7%	14.6%	4.0%	2.1%	13.5%	5.9%	100.0%

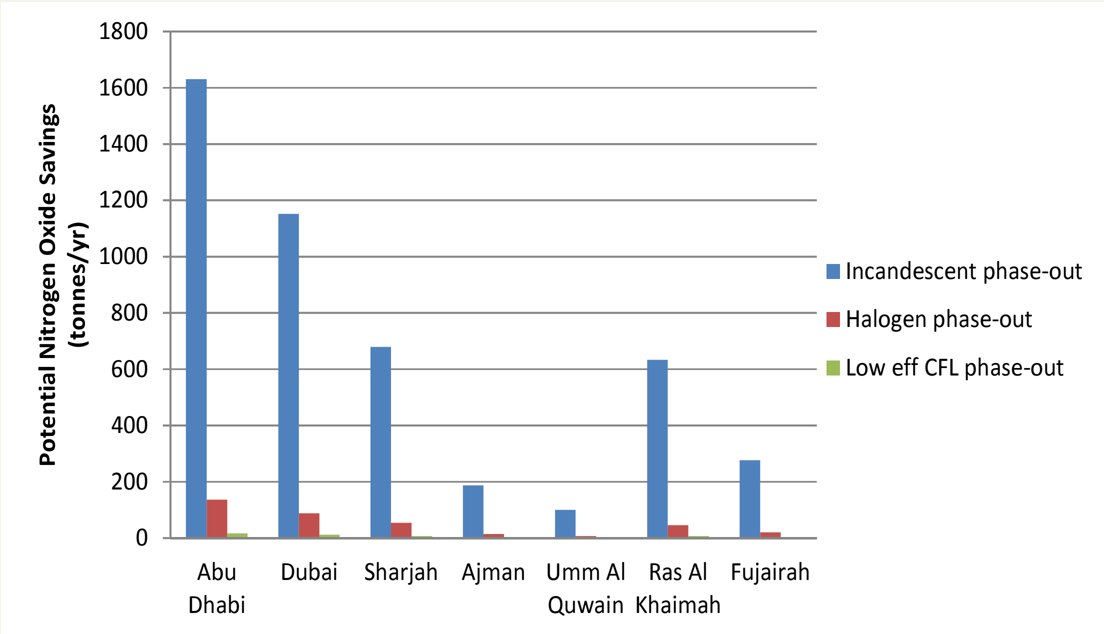

Figure 6. Potential NO_x emissions savings from lamp replacement (tonnes/year).

The annual NO_x savings potential associated with completion of all three phases is nearly 5,100 tonnes, or approximately 7% of all NO_x emissions from Abu Dhabi's entire energy sector in 2010 (SCAD, 2012).

Table 7. Potential SO_x Emissions Reduction from Lamp Replacement (tonnes/year).

	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Incandescent Phase-out	6300	4453	2626	724	388	2444	1067	18001
Halogen Phase-out	527	342	212	57	28	174	80	1420
Low-efficiency CFL Phase-out	68	47	28	8	4	25	11	191
Total	6895	4842	2866	789	420	2643	1158	19612
Percent	35.2%	24.7%	14.6%	4.0%	2.1%	13.5%	5.9%	100.0%

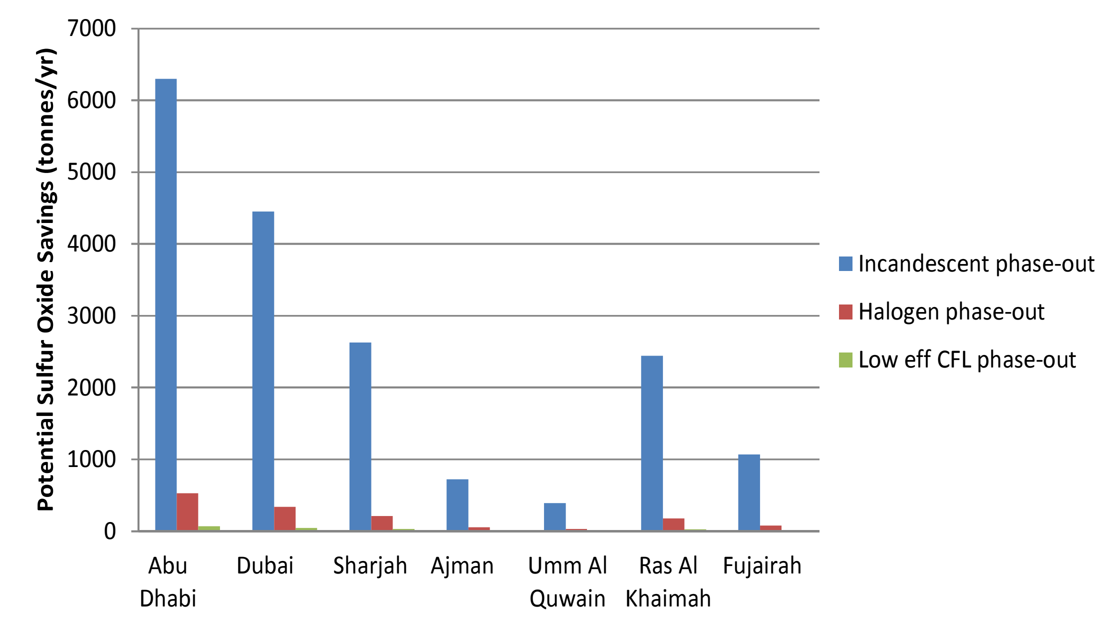

Figure 7. Potential SO_x emissions savings from lamp replacement (tonnes/yr).

The annual SO_x savings potential associated with completion of all three phases is over 19,500 tonnes, or approximately 9% of all SO_x emissions from Abu Dhabi's entire energy sector in 2010 (SCAD, 2012). PM emissions reductions were also estimated. The results are presented below in **Table 8** and **Figure 8**.

Table 8. Potential PM Emissions Reduction from Lamp Replacement (tonnes/year).

	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Incandescent Phase-out	14.3	10.1	6.0	1.6	0.9	5.5	2.4	40.8
Halogen Phase-out	1.2	0.8	0.5	0.1	0.1	0.4	0.2	3.2
Low-efficiency CFL Phase-out	0.2	0.1	0.1	0.0	0.0	0.1	0.0	0.4
Total	15.7	11	6.6	1.7	1	6	2.6	44.4
Percent	35.4%	24.8%	14.9%	3.8%	2.3%	13.5%	5.9%	100.0%

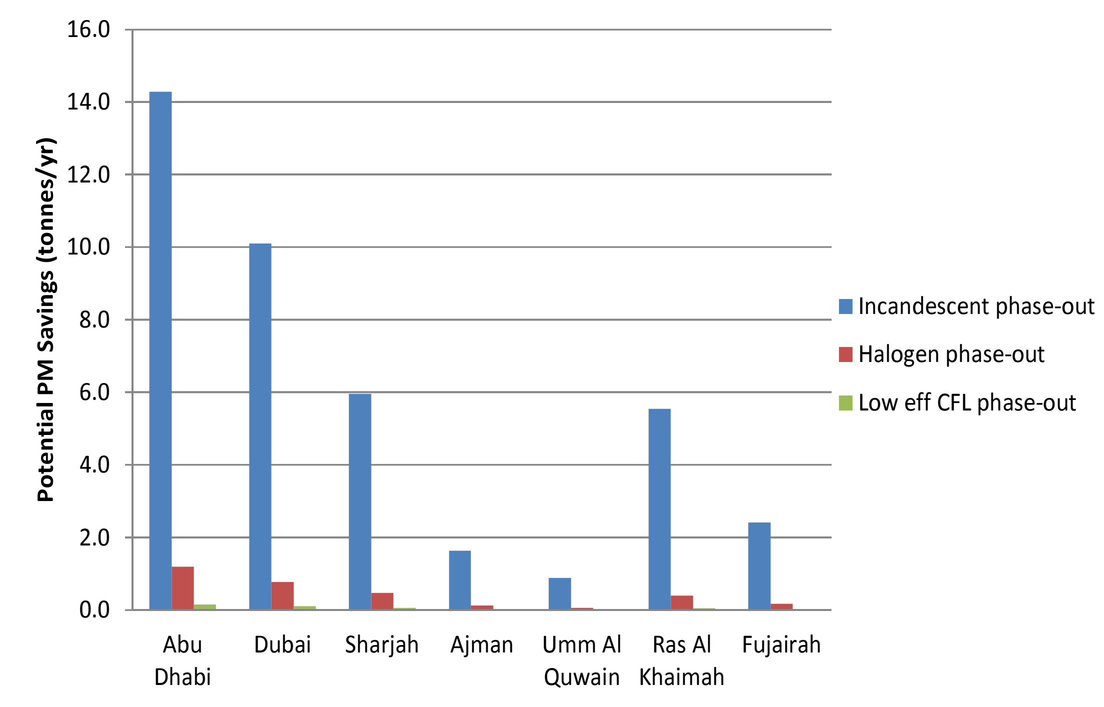

Figure 8. Potential PM emissions savings from lamp replacement (tonnes/year).

Similar to the energy and GHG assessment results, the majority of NO_x, SO_x, and PM savings are realized through the conversion of incandescent lamps to high-efficiency lamps. These savings have the potential to reduce air quality issues and their related effects, including damage to ecosystems and respiratory health problems (SCAD, 2012). Currently, there is not adequate air quality data for UAE. However, work is on-going in the UAE to establish air quality monitoring. Once in place, it will be possible to develop quantitative estimates for air quality-related impacts and potential reductions in impacts due to energy saving measures such as EEL. Due to the larger residential lighting energy demands in Abu Dhabi and Dubai, conversion to EEL in these Emirates would result in the greatest reductions in environmental impacts of residential lighting because of the greater numbers of energy-inefficient lamps that would be replaced.

As noted at the beginning of this section, the estimated impacts above are based on the use phase, shown in the LCAs to be the primary contributor to lighting technology impacts. As such, these estimates reflect the impacts of the natural gas combusted to power the lighting technologies. If other fuel sources or electricity grid mixes are employed, the use phase environmental impacts of technologies would be altered.

4.2.3 Health and Safety

The greatest health and safety concern in converting to EEL is likely mercury contained in CFLs. Mercury in CFLs (and LFLs) is bound in a mercury-phosphor power mixture. The amount of mercury is roughly the volume of the tip of a ball-point pen. If a mercury-containing bulb is broken, one can be exposed to elemental mercury by touching it, after which it can be eaten and/or absorbed through your skin. More importantly for health, one can also be exposed to mercury through the air because elemental mercury vaporizes readily and can thus be inhaled into the lungs (Hu and Cheng, 2012). Once inhaled, the mercury vapor can damage the central nervous system, kidneys, and liver. Mercury is of concern because it is a highly toxic heavy metal that can incrementally accumulate in the environment and animal tissues. Very low concentrations of mercury can adversely impact the neurological development of fetuses, infants, and children. At low concentrations, mercury can affect the human nervous system, reproduction, immune system, cardiovascular system, and kidneys. Mercury can also adversely affect aquatic ecosystems by altering the reproduction of birds and other species, and at high doses, cause lethal toxicity (Hu and Cheng, 2012).

Although we found different scientific and media sources to present contradictory information about the significance of mercury from CFLs and LFLs, most government sources (e.g., U.S. EPA, 2012b) pointed to mercury exposures from broken CFLs/LFLs as not likely to present a health risk to individuals or households, especially if proper precautions and clean-up are conducted. This is due to several factors, including the amount and duration of exposures and the specific type of mercury to which one is exposed. As an example, assume a CFL containing 5 mg of mercury breaks in a bedroom that has a volume of about 25 m^3. The entire 5 mg of mercury vaporizes immediately (an unlikely occurrence), resulting in an airborne mercury concentration in this room of 0.2 mg/m^3. This concentration will decrease with time, as air in the room leaves and is replaced by air from outside or from a different room. As a result, the concentrations of mercury in the room will likely approach zero after about an hour or so. Under these relatively conservative assumptions, this level and duration of mercury exposure is not likely be dangerous. Overall, the 8-hour exposure (calculated as .025 mg/m^3) is lower than the U.S. Occupational Safety and Health Administration standard of 0.05 mg/m^3 of metallic mercury vapor averaged over 8 hours.

Most governmental agencies recommend taking extra precautions to minimize mercury exposures because some studies have shown the potential for acute exposure exceeding thresholds.[9] The U.S. Environmental Protection Agency (EPA) publishes guidelines[10] about the specific steps that you should take to clean up mercury in the event that a CFL breaks in your home. The EPA recommends the following:

1. Windows are opened immediately to reduce mercury concentrations inside the room/home;
2. Spilled mercury is not touched directly;
3. Broken CFL glass is cleaned up carefully and immediately (but not directly with hands or a vacuum cleaner); and
4. Affected area is wiped with a paper towel to remove all glass fragments and mercury. The EPA further recommends that the paper towel and glass fragments be placed in a sealed plastic bag and brought to a hazardous waste collection site.

4.3 End-of-Life Impacts

All fluorescent lamps contain a small amount of mercury, which is necessary for the lamps to emit visible light (Navigant, 2009).

4.3.1 Waste Generation

The overall lamp waste generated from spent lamps in UAE was estimated by multiplying the number of bulbs present in UAE households by the annual replacement rate and weight of each lamp type, as shown in **Table 9**. Because the weight of each lamp may vary according to type and manufacturer, high and low estimates were calculated. For the UAE, we assume that lamps are illuminated an average of 2 hours per day. **Figure 9** illustrates the estimated lamp waste associated with each scenario.

The waste estimates indicate that phasing out incandescent lamps could result in a decrease of overall waste generation by approximately 700 tonnes per year (using mid-points of the ranges), or a 36% decrease. Even though the replacement scenarios would decrease waste generation by this amount, it is a relatively small fraction of the total waste generated in the UAE. For example, estimated solid waste generation for the Emirate of Abu Dhabi alone is 5.7 million tonnes per year (15 percent, or 855,000 tonnes, is characterized as municipal solid waste) according to data obtained from a waste inventory conducted by the Center of Waste Management (AD CWM, 2009). The savings can be attributed to the long lifetime of EEL. Spent lighting products are most likely only a small fraction

[9] http://www.maine.gov/dep/homeowner/cflreport.html
[10] http://epa.gov/cfl/cflcleanup.html

Table 9. Life Expectancy, Replacement Rate, and Weight per Lamp Type In UAE.

Lamp Technology	Life Expectancy (hours)	Annual Number of Lamps Used per Type in UAE	Annual Replacement Rate (% of lamp type discarded per year)	Annual Number of Discarded Lamps per Type in UAE	Weight of Lamps per Type (low estimate in g)	Weight of Lamps per Type (high estimate in g)
Incandescent	1000	5,645,220	73%	33,321,011	30	32
Low-efficiency CFL	3000	2,830,733	24.3%	688,812	91	110
High-efficiency CFL	10,000	16,040,820	7.3%	1,170,980	91	110
Linear Florescent	24,000	14,020,273	3%	426,450	226.5	2780
Halogen	2000	6,384,393	36.5%	2,330,303	29.2	29.2
LED	50,000	105,046	1.5%	1,534	280	520
Total				37,939,090	747.7	3581.2

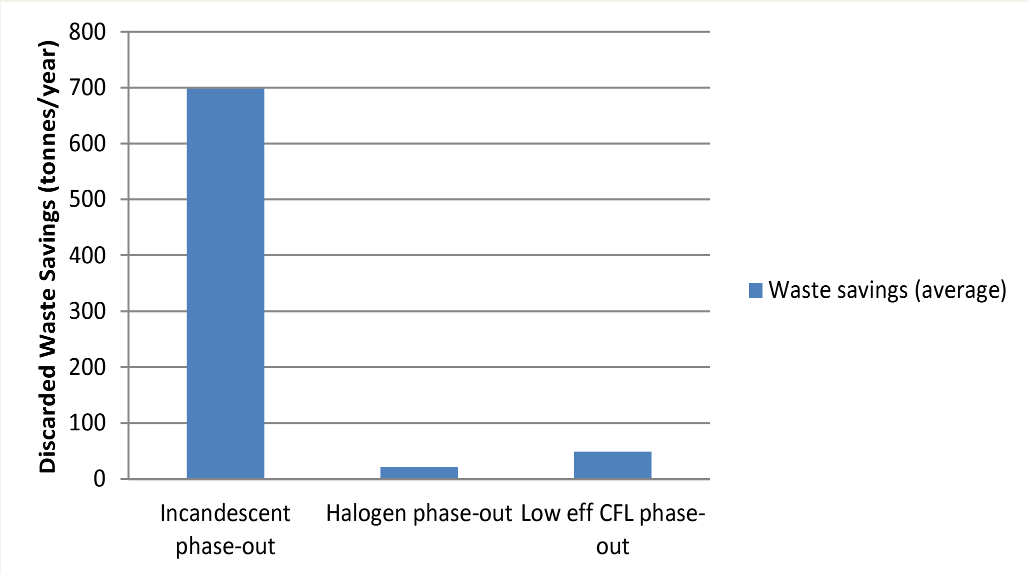

Figure 9. Annual estimated amount of generated waste from replacement of spent lamps in UAE.

of the annually generated waste in the Emirates. However, conversion from low- to high-efficiency lamps represents an opportunity for a reduction in disposal volume.

End-of-life management of spent fluorescent light bulbs is a particular area of concern since disposing of fluorescent bulbs in the trash often breaks their fragile glass casing, releasing mercury into the environment (Hu and Cheng, 2012). Even if the bulbs manage to remain intact after being disposed, these products will likely be broken during transport and end up in landfills, where they will eventually release toxic chemicals (VITO, 2009; Hu and Cheng, 2012). LED lamps were not found to have any similar issues with respect to toxic or hazardous constituents that would pose concern at the end of life.

CFL lamps generally contain between 1.4 to 5 mg of mercury per CFL lamp (Hu and Cheng, 2012; VITO, 2009; New Zealand Ministry for the Environment [NZ MfE], 2009). LFLs generally contain 4 to 12 mg of mercury (NZ MFE, 2012). Using these mercury levels as low- and high-level estimates of the mercury in CFLs that could potentially be released during end-of-life processes, the additional amount of mercury discarded annually under each lamp replacement phase was estimated, relative to the baseline. Results of the estimate are shown in **Figure 10**.

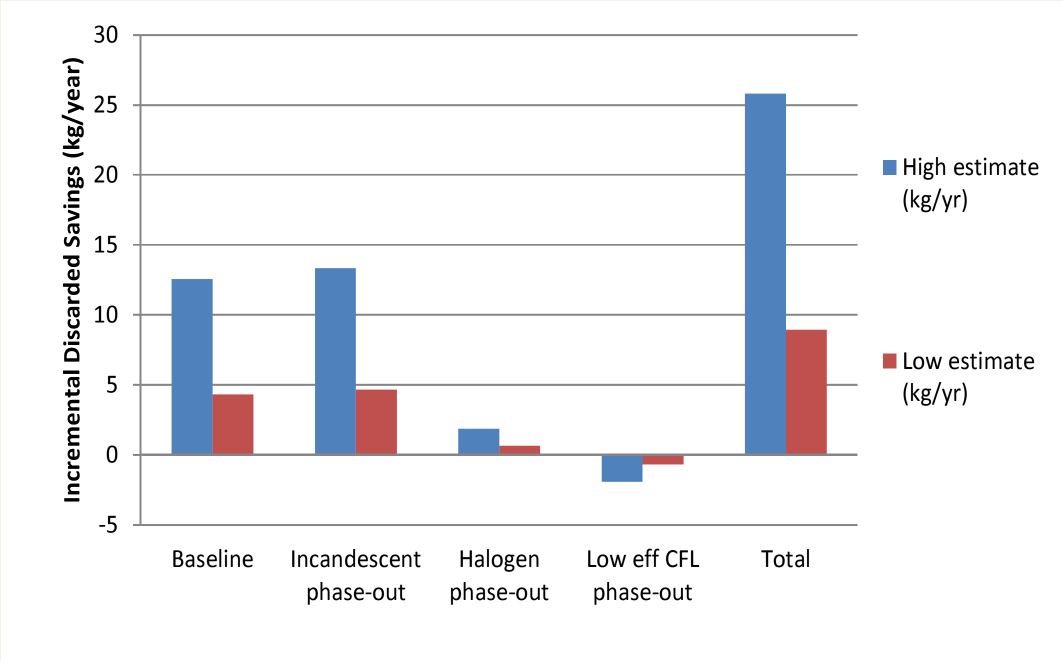

Figure 10. Annual estimated amount of mercury discarded from replacement of spent lamps with CFLs (kg/yr).

The estimated amount of annually discarded mercury from the highest scenario is approximately 26 kg/yr, generating approximately 13 kg/yr more mercury than the baseline scenario. The increase in mercury discarded annually due to the phase-out of incandescents and halogens corresponds to an increase in the number of high-efficiency CFL lamps employed in the UAE residential sector. The decrease in mercury discarded annually due to the phase-out of low-efficiency CFLs corresponds to upgrade to high-efficiency CFLs, which have a longer lifetime and are therefore less often discarded. In general, conversion to high-efficiency bulbs is accompanied by conversion to bulbs with longer lifetimes, with smaller numbers of lamps being discarded annually.

Figure 11 compares this estimate to discarded mercury estimates from lamps in European Union countries in 2000 (UNEP, 2008). As illustrated in Figure 11, the annual discarded mercury from lamps in UAE is comparable to several smaller European countries.

4.3.2 Waste Management

Currently, most of the waste generated in the UAE is disposed of in landfills. Some of these landfills, such as Al Dhafra in Abu Dhabi, do not have liners or other protective elements of modern sanitary landfills to prevent leachate from entering the soil and groundwater. Recycling of spent mercury-containing bulbs in the UAE has been minimal to date, limited to the one (now stopped) pilot

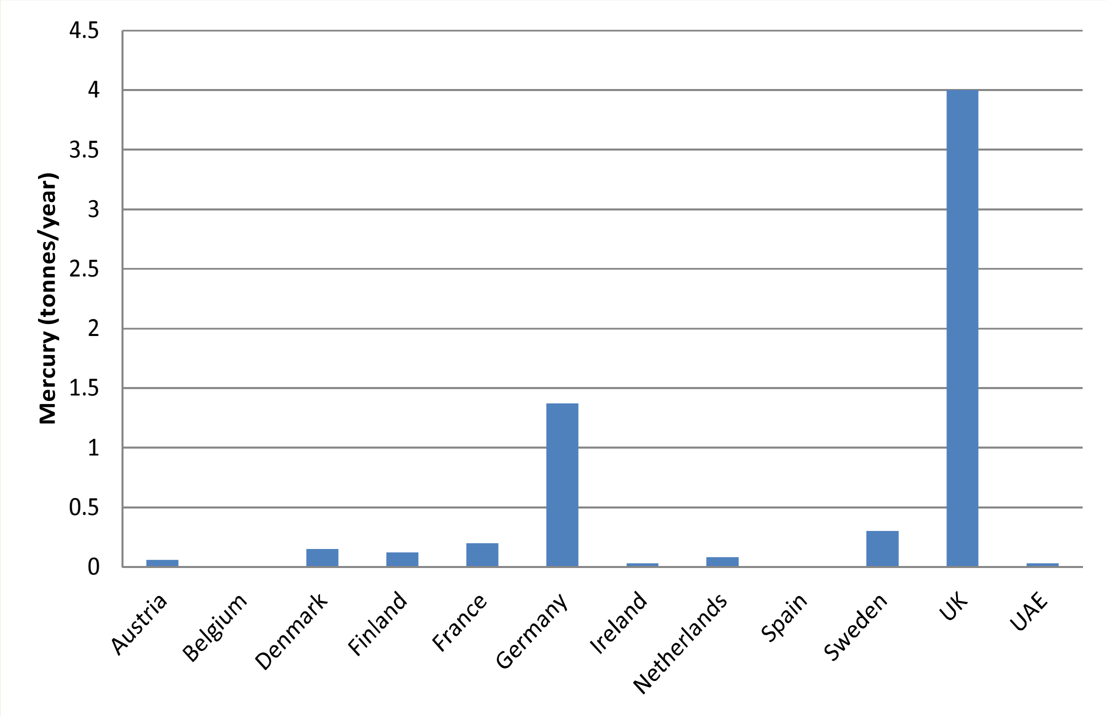

Figure 11. Estimated mercury from discarded lamps in tonnes per year (UNEP, 2008).

operation at ENPARK. Recycling entails crushing the bulbs in a controlled environment and separating the phosphor-mercury powder, glass, and metals. Only one spent-bulb recycling center was identified in the Emirates. ENPARK has been operating a spent-bulb recycling center since 2010. However, mercury and other materials collected are currently being stockpiled until further guidance is received from the government about its proper management.[11]

There are relevant UAE hazardous waste laws, in particular Federal Law No. (24) of 1999 (MoEW, 1999) concerning the Protection and Development of the Environment which mandates the proper disposal of hazardous wastes, and related Cabinet Order 37 of 2001 (MoEW, 2001) that provides requirements for implementation of Federal Law 24. However, the Federal Law 24 is very general and Cabinet Order 37 does not provide specific guidelines or requirements for mercury or mercury-containing lamps. The UAE is also a ratified member of the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. The Basel Convention working group on mercury-containing wastes (which includes mercury-containing lamps) has prepared technical guidelines (UNEP, 2011) concerning the proper recycling and land disposal of mercury-containing lamps. Federal Law 24 and the Basel Convention provide the necessary foundation for development of specific mercury-containing bulb disposal requirements in the UAE.

The Basel Convention technical guidelines recommend the development of a closed mercury system where mercury-containing waste, such as spent lamps, be separated from standard waste streams and collected for management in a manner that minimizes release of mercury into the environment. The guidelines state that mercury should then be recovered for reuse through recycling or, if no reuse is possible, disposed of in a permanent storage system. **Table 10** provides an overview of closed mercury system processes.

[11] http://gulfnews.com/news/gulf/uae/environment/safe-disposal-of-lightbulbs-necessary-1.788055

Table 10. Guidelines for end-of-life management of mercury-containing lamps (source: UNEP, 2011).

End of Life Process	Pre-treatment	Treatment	Recovery	Final step
Recovery of mercury	Separation of Lamp Materials. Air separation and Mechanical Crushing are common methods to separate glass, end-caps and mercury-phosphor powder.	Thermal treatment and Volatilization of mercury. Roasting or Retorting with mercury collection device. Flue gas treatment is also recommended to mitigate mercury emissions in flue gas and fly ash.	Condensation and distillation of recovered mercury. Mercury undergoes oxidation, precipitation and adsorption of mercury before it is purified during distillation.	Re-use mercury
Disposal	Mobility Reduction. This process is recommended to stabilize or solidify of mercury through addition of stabilizing agent such as sulphur or solidifying additive such as Portland cement to bind mercury. Amalgamation can also be used, but leaching probability is higher.	Placement of mercury in specially engineered landfill or special containers in an underground facility. If mercury compounds are capable of leaching mercury above the national and state regulations (generally between 0.005 and 0.2 mg/L), mercury should be disposed of in a landfill where inflow and outflow of substances is prevented on all sides.	None	Permanent Placement in Landfill or Underground Facility. Underground facilities may include disused mines or hard rock formations.

Table 11 includes a summary of current waste management for household hazardous wastes (e.g., batteries, mercury-containing lamps) by Emirate. This information was collected through an informal survey of waste management agencies in each Emirate. In general, no specific plans or programs for handling mercury-containing lamps from the residential sector are currently in existence or planned. The Emirates of Dubai and Abu Dhabi, the two largest bulb markets, are currently preparing master plans for waste and these could include planning for household hazardous waste management (including mercury-containing lamps). The Dubai master plan is currently being prepared by Dubai Municipality and is due for release in late 2012. The Abu Dhabi master plan is planned to begin in late 2012 by the Center of Waste Management and completion in 2013.

Table 11. Current Policies and Practices in the UAE Relating to Spent Mercury-Containing Lamp Disposal.

Aspect	Summary of Current Practice in the Emirates
Current waste-related laws or policies for Hg-containing lamps	There are no laws or policies that are specific to Hg-containing lamps in any of the Emirates. However, since they can contain hazardous material, they should fall under Law No. 24 of 1999 (and related Cabinet Order No. 37 of 2001). In general, facilities (including recycling facilities) have not received Hg-containing lamps as separate waste, but rather mixed with general waste. No other specific laws or policies are available on this issue.

Aspect	Summary of Current Practice in the Emirates
Current infrastructure and/or programs exist for recycling of spent Hg-containing lamps	There are no practices or programs that are specific to the management of Hg-containing lamps. Some companies, however, are doing recycling for batteries and e-waste, but it is not clear that there are any programs for spent Hg-containing lamps hazardous waste. No collection-specific points for spent Hg-containing lamps have been dedicated, and this will required approval from municipal and other governmental agencies. For electronics waste, there is no separation done by customers, and therefore, it is received with general waste. No recycling programs are currently implemented. Setting up new recycling facility for spent Hg-containing lamps at 18 tons per day capacity might cost around 40 to 50 million AED.
Current or potential markets for any recovered materials (e.g., glass, metals, mercury)	There are a number of glass manufacturing companies and some metals manufacturing, but it is not clear if they would be able to use recovered glass and metals. There are no current markets for mercury.
Current export of waste (particularly special wastes such as batteries, electronics, etc.)	No waste is currently exported.
Design of landfill for disposal of hazardous materials such as Hg-containing lamps	There are a number of landfills designed with liner systems but these are not double-lined systems as required for hazardous waste landfills. In some cases, there is no dedicated site for hazardous waste disposal, and Hg-containing lamps (and other household hazardous wastes) are disposed of with general waste. However, the Emirates are moving towards having either sections of landfills dedicated only for the hazardous waste disposal, or completely separate hazardous waste landfills, and Hg-containing lamps could be disposed in either of these.

Although the amount of mercury in a single fluorescent lamp is small, the large numbers of fluorescent lamps in use and eventually discarded will contribute to the amount of mercury that is released into and accumulates in the environment. Several options exist that allow countries to benefit from energy savings associated with EEL, such as CFLs and LFLs, while minimizing the potential amount of mercury released into the environment. For example, several countries place limits on the amount of mercury allowed in lamps, as summarized in **Table 12**. For the UAE, we recommend that mercury content limits be established to meet international best practice, such as the European Union's RoHS directive[12], which specifies a limit of 2 mg mercury for 12W CFLs.

Table 12. Examples of Regulated Lamp Mercury Content Limits by Country

Country	Lamp Type	Mercury content Limit	Reference
Australia	CFLs	5 mg per lamp	AG, 2012
	LFLs	15 mg per lamp	
Canada	CFLs and LFLs	Reduce content by at least 80% from 1990 to 2010	Hilkene and Friesen, 2005
China	CFLs and LFLs	10 mg per lamp	UNEP, 2010

(continued)

[12] http://www.bis.gov.uk/nmo/enforcement/rohs-home

Table 12. Examples of Regulated Lamp Mercury Content Limits by Country (continued)

Country	Lamp Type	Mercury content Limit	Reference
European Union member countries	CFLs	Currently: 5 mg per lamp By 2012: 3.5 per lamp By 2013: 2.5 mg per lamp	European Commission, 2010; UNEP, 2010
	LFLs	Currently: ▪ 10 mg in halophosphate lamps ▪ 5 mg in triphosphate lamps with a normal lifetime ▪ 8 mg in triphosphate lamps with a long lifetime By 2012: ▪ 3-4 mg in triphosphate lamps with a normal lifetime ▪ 5 mg in triphosphate lamps with a long lifetime	
California	CFLs	5 mg per lamp	CA DTSC, 2012
	LFLs	10 mg in halophosphate lamps 5 mg in triphosphate lamps with a normal lifetime 8 mg in triphosphate lamps with a long lifetime	

Several technologies exist which enable manufacturers to ensure that the amount of mercury in the lamps adhere to mercury limiting regulations while meeting the required lamp performance. Examples of technologies include injecting precise amounts of mercury using mercury amalgam, mercury alloy pellets, mercury alloy rings, or mercury capsule (UNEP, 2011). These technologies allow manufacturers to reduce the amount of mercury used and in some cases replace elemental mercury with less hazardous forms, while minimizing environmental and health hazard risks during manufacturing, transportation, installation, use, storage, recycling and disposal, especially if lamps break (UNEP, 2011).

Limiting mercury disposal can also be achieved by developing spent-bulbs recycling programs. Recycling programs can include the following:

- **Municipal collection and recycling**. These programs are typically organized and implemented by municipalities. Light bulbs may be collected at designated collection sites or may be picked up curbside, similar to other recycling programs.
- **Retailer take-back**. Some retailers, such as home improvement, home furnishing, and other stores that sell bulbs, may have programs that allow spent bulbs to be dropped off at the store.
- **Reverse vending machine**s. Vending machine-style recycling units, for example the reVend Light Bulb Recycling Reverse Vending machine in the UK[13], are designed to accept domestic light bulbs. The machine automatically dispenses of the l bulb and there is often a reward or monetary incentive (e.g., coupon or cash back) provided.
- **Mail-back services**. Some bulb manufacturers and other organizations sell pre-labeled recycling kits that allow businesses and residents to mail used bulbs to recycling centers. The cost of each kit includes shipping charges to the recycling center. An individual can fill up a kit with old bulbs, seal it, and bring it to the post office or leave for his or her postal carrier.
- **Extended Producer Responsibility (EPR) programs.** ERP programs are generally implemented by regulating agencies and require lamp manufacturers to take responsibility for the post-consumer stage of lamp products. Depending on the country, manufacturer agreement and regulations set, manufacturers may be required to provide information on how and where recycling opportunities exist. Information can be provided on lamp packaging, through websites or other forms of outreach. In others, manufactures may be required to

[13] http://www.light-bulb-recycling.co.uk/index.html

ensure that their products are managed properly at end of life through recycling or waste treatment through take back programs or other initiatives.

Government-supported actions of various recycling programs exist throughout the United States, Europe, and Asia to facilitate the collection of mercury-containing lamps. **Table 13** provides examples of existing recycling programs at national, municipal, and voluntary levels from various countries.

Table 13. Examples of Recycling Programs from Various Countries

Country	Lamp Recycling Rate	Policy/Effort	Reference
Austria[9]	>50% recovery rate in early 2000s	Requires consumers to pay deposits (some refundable) at the time of lamp purchase in order to fund recycling programs.	Hilkene and Friesen, 2005
Australia	2% in 2009	No national strategy; however, the country promotes "Fluorocycle," an initiative to increase commercial and industrial lamp recycling. Some states have initiated recycling programs and pilot programs. Private mercury recyclers provide and collect lamp recycling kits at retail locations.	NEWMOA, 2008; Australian Government, 2012
Brazil	6% in 2007	No national strategy; however, some states ban landfilling and incineration.	Laruccia et al., 2011
Canada	7% in 2004	No national strategy; however, some local and provincial governments provide lamp recycling to residents. Recycling awareness campaigns that provide consumers with the locations of lamp recycling options are available through the Environment Canada. Private mercury recyclers provide pre-paid lamp recycling kits and take back lamps from various retailers and collection centers.	Hilkene and Friesen, 2005
China	4%	No national strategy; however, a nonprofit-private partnership has pledged to collect and recycle CFLs.	TCP, Inc., 2008
Germany[14]	42% in 2008	Requires manufacturers to operate a national return system for their collection and recycling (Lightcycle Retourlogistik und Service GmbH).	Hilkene and Friesen, 2005
Japan	9% in 2003	No national strategy, but participating areas collect CFLs separately from municipal waste and send to recycling organizations.	Japan Ministry of the Environment, 2011
Korea	19% in 2005	Implemented volume-based waste collection fee system, enforced recycling through deposit system or EPR, and provided assistance programs to recycling industries.	UNEP, 2010
Mexico	<10%	No national strategy; however, some manufacturers collect lamps taken back to retail locations.	European Commission, 2008

(continued)

[14] As part of the European Union, manufacturers are required to collect and recycle mercury-containing lamps (retail price of a CFL lamp includes the cost for recycling). Manufacturers and retailers must also provide information to consumers about where they can recycle their CFLs.

Table 13. Examples of Recycling Programs from Various Countries (continued)

Country	Lamp Recycling Rate	Policy/Effort	Reference
New Zealand	9% in 2007	No national strategy; however, some regional councils provide recycling to residents. Private mercury recyclers provide pre-paid lamp recycling kits and take back lamps from collection centers.	NZ MfE, 2012
Sweden[9]	75% in 2007	Requires manufacturers to collect discarded lamps from customers and, in some cases, pay for mercury recovery.	NEWMOA, 2008; Energy Efficient Residential Lighting Initiative (Enerlin), 2008
Taiwan	87% recovery rate in 2003	Requires all lamps to be recycled and all stores that sell lamps to accept them back for recycling, facing fines otherwise.	Hilkene and Friesen, 2005
United Kingdom[9]	Not found	Promotes "Recycle-more," a website that provides consumers with the locations of lamp recycling facilities available to them.	Hilkene and Friesen, 2005
United States	24% in 2003	Mercury-containing lamps (or all mercury-containing items) are regulated as "universal waste," which "increases flexibility in the management of lamps, streamlines requirements for waste handlers, and promotes recycling". Recycling awareness campaigns that provide consumers with the locations of lamp recycling options are available through the EPA and states. Private mercury recyclers provide pre-paid lamp recycling kits and take back lamps from various retailers and collection centers.	U.S. EPA, 2009
VT, CA, MN, NY, ME, CT, and RI		States have either banned the disposal of mercury-containing lamps or have limited the amount of lamps entering disposal facilities.	NEWMOA, 2008

Rates of recovery of mercury-containing lamps vary widely from country to country. A common feature of countries with greater recovery rates is the presence of strong top-level government policies, such as the European Union's Directive on Waste Electrical and Electronic Equipment (WEEE[15]), which makes manufacturers fully responsible for managing product wastes. EPR programs such as this can shift the responsibility for end-of-life management of products to the producer and relieve municipalities of the waste management burden. EPRs can also incentivize the importance of environmentally-friendly design so that the environmental costs of treatment and disposal are minimized and/or incorporated into the purchase cost. EPR can be implemented through mandatory, negotiated or voluntary approaches. The Basel Convention recommends that if EPRs are implemented, "Environmental authorities should develop regulatory frameworks providing responsibilities of relevant stakeholders, standards for mercury contents and management of products, and components of EPR programs and encourage participation by relevant parties and the public. They should also be responsible for monitoring the performance of EPR programs (e.g. amount of wastes collected, amount of mercury recovered and costs accrued for collection, recycling and storage) and for recommending changes as necessary. The responsibility should be placed on all producers of the products considered, and free riders (producers who do not share their responsibilities) should not be allowed, otherwise, other producers are forced to bear costs which are disproportionate to their product market share." (UNEP, 2011)

The WEEE Directive also sets collection, recycling and recovery targets for all types of electrical goods, with a minimum rate of 4 kilograms per head of population per annum recovered for recycling by 2009. The European Union's Directive on the restriction of the use of certain hazardous

[15] http://www.environment-agency.gov.uk/business/topics/waste/32084.aspx

substances in electrical and electronic equipment (commonly referred to as the Restriction of Hazardous Substances Directive or RoHS[16]) restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is closely linked with Directive on WEEE and is part of a legislative initiative to solve the problem of huge amounts of toxic e-waste.

Lamp recycling programs can have a large influence on the health and environmental impacts that lighting technologies have during the end-of-life phase. Additionally, materials reclaimed from the end-of-life phase can be used to reduce the energy and materials needed for extraction and manufacturing of new lamps. The material benefits from recycling are becoming increasingly important as lighting technologies become more sophisticated and employ varying quantities of rare earth materials and metals (NZ MfE, 2012a). Virtually all components of a fluorescent bulb, including metal end caps, glass tubing, and phosphor-mercury powder, can be separated and recycled. Recyclers often sell the metallic portions as scrap metal. The recycled glass can be remanufactured into other glass products. The mercury must be separated from the phosphor-mercury power through additional processing in order to be reused. Once separated, it can be recycled into new fluorescent lamps and other mercury-containing devices.

Several countries have elected to promote the adoption of energy-efficient CFLs to take advantage of the energy savings, but also promote the use of low mercury-containing bulbs through programs or regulations and/or implement lamp recycling programs (NZ MfE, 2012b; U.S. EPA, 2009; VITO, 2009). Some notable examples of these actions include the following:

- Requiring manufacturers to commit to significant reductions in lamp mercury content over time (multiple countries).
- Easing hazardous waste regulatory requirements for mercury-containing lamps (or all mercury-containing items). For example, in the United States,[17] "universal waste" rules promote recycling and proper disposal by easing certain regulatory requirements for certain low risk hazardous waste that are generated by many industries. These wastes typically are generated by many different businesses and households and include lamps. Specifically, universal waste, unlike other hazardous waste, does not have to be tested by the generator, does not have to be manifested and collectors who only store universal waste are not required to get a hazardous waste permit. These streamlined waste processing requirements are an incentive to encourage recycling. If the waste is not recycled, it must be processed and managed using the standard requirements.
- Requiring that all manufacturers take back lamps at end of life and providing large numbers of public lamp collection sites for consumers to drop off all lamp types (Germany, 42% recovery rate in 2008).
- Requiring all stores that sell lamps to accept them back for recycling, or face fines (Taiwan, 87% recovery rate in 2003).
- Require that all lamps be recycled, making it illegal to dump them in common waste streams (Taiwan).
- Requiring consumers to pay deposits (some refundable) at the time of purchase in order to fund recycling programs (Austria, greater than 50% recovery rate in early 2000s).

These types of programs can minimize end-of-life impacts through managing the amount of mercury released in the environment and provide material reuse benefits of recycling. It is unlikely that high mercury-containing lamp recovery rates, such as those in Europe and Asia, can be achieved quickly, especially in cases such as the UAE where few to no recycling systems currently exist.

[16] http://www.bis.gov.uk/nmo/enforcement
[17] http://www.epa.gov/osw/hazard/wastetypes/universal/lamps/faqs.htm

Some of the above actions and policies may be useful for implementing a mercury-containing lamp recovery system, but actions below the top-most level of government may be necessary to test and initiate new recycling programs, as well as limit the amount of mercury that is released into the environment. Specific recommendations for the UAE context are provided in **Section 6**. In addition, the ESMA Sustainability Committee is currently drafting a guidance document (ESMA, 2012) on the safe disposal of lighting products containing mercury in the UAE. Since some EEL products such as CFLs contain mercury, and adoption of standards for lighting regulation will increase the use of EEL in the UAE, it is particularly important to indicate how spent lamps containing mercury should be safely disposed. The guidance will closely follow the relevant technical guidelines from the BASEL Convention with regards to safe disposal of mercury containing lamps (see UNEP, 2011) , as well as recommendations from the UNEP *document Achieving the Global Transition to Energy Efficient Lighting Toolkit* (UNEP, 2012). The guidance document includes provisions for all stages of spent lamp management from safe collection, transport, storage, treatment (recycling), and disposal for non-recycled materials. It will also include options for financing spent lamp collection and treatment infrastructure, as well as the need for outreach programs educate consumers (residents) about safe handling and cleanup procedures for when a mercury containing lamp breaks. The document also contains the full text for Cabinet Order No. 37 regarding the implementation of Executive order of Federal Law No.24 for 1999 on Handling of Hazardous Substances, Hazardous Wastes and Medical Wastes. Although Cabinet Order No. 37 does not contain any specific provisions related to spent mercury-containing lamps, it does provide precedent for the safe collection, handling, transport, storage and disposal for domestic sources of hazardous waste, which spent mercury-containing lamps could fall under.

The Sustainability Committee is also currently weighing different options for collection and treatment of spent EEL products. The committee concluded that establishing collection at the household level is likely not practical and would be costly, mainly because the relatively little waste generated from spent light bulbs would not justify setting such a collection program. One option being considered is to have a single centralized UAE recycling center managing both mercury-containing lamps and other electronics waste. The individual Emirates or manufacturers and retailers would then set up waste collection centers for residents to take their spent lamps.

5. Economic Impacts of Lighting Technologies

The direct economic impacts of upgrading to EEL are detailed in the *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b) and capture both the household and government perspectives. The residential tariff rate in large part determines if upgrading to EEL generates net benefits for the household. The difference between the tariff rate and the full cost of power generation determines the level of subsidy being provided by the government, which drives the government's economic perspective. The benefit/cost analysis conducted by RTI (2012b) was done on an individual lamp basis and the varied tariff rates by Emirate and nationality (Nationals versus non-nationals) was considered. Thus, replacing an incandescent lamp in Dubai has a different impact on a household's electricity bill compared to replacing an incandescent lamp in Abu Dhabi. In addition, within some Emirates (Abu Dhabi and Sharjah), villas owned by Nationals pay a lower tariff rate than apartments. This level of disaggregation was employed in conducting the household benefit/cost analysis.

In the aggregate, UAE households will realize significant savings on their electricity bills. The benefit/cost analysis conducted by RTI (2012b) reports household savings by Emirate and type of housing. Electricity bill savings in the UAE total 459 million AED per year. After accounting for approximately 7 million AED in higher household expenditures for purchasing EEL, the net savings for the UAE totals almost 452 million AED per year.

From a government perspective, UAE governments subsidize the provision of electricity. Electricity subsidies provided by the governments are defined as the difference in the full cost of power generation and the revenue received by the distribution companies through electricity tariffs.

RTI (2012b) estimated the benefit from adopting EEL as reduction in electricity subsidy provided by the governments, and this amounts to an annual savings of approximately 216 million AED.

From a social perspective, the benefit from adopting EEL is the combined household benefits and the subsidy provided by the governments. Full social benefits are the sum of the household sector benefits and the subsidy reduction from power generation, less the increase lamp costs. Residential lighting standards that phase out incandescent, halogen, and low-efficiency CFLs could generate significant economic benefits for the UAE. According to the *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b), social benefits are estimated to be 668 million AED per year based on switching to CFLs. Subsidy reduction to the government would account for 216 million AED of these benefits, with the remaining 459 million AED going to households in the form of lower electricity bills. Switching to LEDs generates approximately same benefit because LEDs are approximately the same efficiency (lumens/watt) compared to CFLs.

The social payback period for a wholesale upgrade to CFLs would be approximate 1.1 year. This means that the full cost of switching incandescent, halogen, and low-efficiency CFLs to high-efficiency CFLs would be covered by the reduction in electricity production costs in 13 months. From the government's perspective, if they were to fully fund the transition with subsidy reductions, the payback period would be approximately 3.4 year. Both the social and government payback periods strongly support aggressively moving forward with residential lighting standards.

LEDs also represent an attractive option with current savings and annualized costs comparable to, but both slightly less than, CFLs. However, the 5- to 7-times higher price of LEDs increase the payback period from the social and government perspective to 8.5 and 26.2 years, respectively. Wholesale upgrade to LEDs would cost over 5 billion AED. For this reason it is anticipated that CFLs will be the dominate EEL in the global market for the near future. However, as LED technology improves in terms of efficiency and price, policy makers will want to consider promoting LED adoption in the future to take advantage of their environmental benefits (e.g., less toxic metals).

Indirect impacts, such as the cost of lamp disposal or changes in respiratory health issues, may also occur as a result of changes in residential lighting. For example, converting to EEL may reduce GHG emissions, air pollution, and landfilled materials, as discussed in the environmental section. Potential cost savings from these reduced environmental impacts as a result of EEL includes the following:

- reduced risk of cardiopulmonary health issues that have been associated with emissions from fossil fuel burning;
- decreased burden on landfills and transport to landfills; and
- reduced damage to buildings and structures from acidic compounds in the atmosphere

End-of-life management costs vary, depending on the type of lamp, quantities, and whether transportation is included. Currently in the UAE, landfill disposal fees are minimal. Minimal disposal fees and the relative low tonnage of bulbs disposed annually make landfill disposal the cheapest option. Cost data and information for spent-bulb recycling is extremely limited and what is available is very generic. The following generic price ranges, as provided by the EPA,[18] are typical:

- Tubes – 4¢ to 12¢ per linear foot
- High-Intensity Discharges – $1.50 to $2.00
- Compact Fluorescent Lamps – 50¢ to $1.00

[18] http://www.epa.gov/osw/hazard/wastetypes/universal/lamps/recycle.htm

A specific EPA study (EPA, 2001) conducted a survey of small-scale fluorescent lamp crushers reported recycling costs in the range of 6¢ to 11¢ per linear foot for intact bulbs and $250 to $450 per 55 gallon drum filled with crushed lamps. According to discussions RTI had with the Association of Lighting and Mercury Recyclers[19], the direct cost for users to get the discarded CFL's to a crushing center is approximately $0.50-1 per bulb, while giving intact ones to a consolidator for transport to the large crusher costs approximately $1.50 per bulb. In terms of capital costs, a small scale crusher cost was estimated to range between $3,000-10,000 per unit and typically is used for direct collectors processing approximately 10,000 bulbs per month. Large commercial crushers, typically the type that large retailers (e.g., Home Depot) and manufacturers use can costs $300,000-1,000,000. A general breakeven volume for the large operations, which guides the return on investment, was estimated to range from 2 to 5 million bulbs per year. Another company, MRT[20] , provided an estimate for breakeven at approximately 1 million bulbs per year.

If conversion to CFLs is implemented in the UAE, there is a small, but present potential risk of mercury exposure from fluorescent lamps. Possible mercury exposure pathways may generate hazardous waste processing costs or health care costs, if individuals are ultimately exposed to the mercury. However, health costs may be mitigated by educating the public on proper CFL disposal methods. Mercury is present in a number of products. **Figure 12** (NEWMOA, 2008) indicates the relative amounts of mercury in common household products.

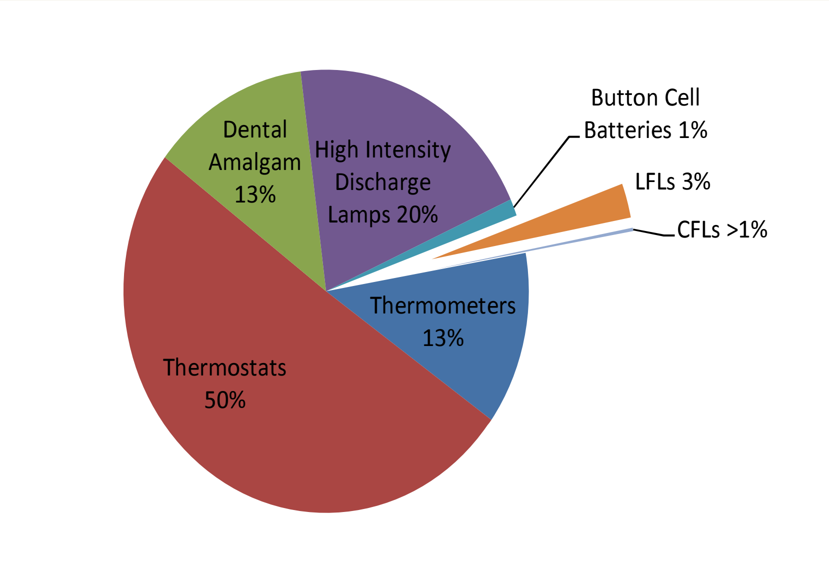

Figure 12. Relative amounts of mercury contained in individual products commonly found in residences (NEWMOA, 2008).

Overall, conversion of residential lighting to EEL has been identified as economically beneficial activity both in terms of energy use and related environmental impact reductions. McKinsey (2011) estimated that switching residential lighting to LED lamps in relation to other climate-change mitigation strategies is the one of the most cost-effective climate-change initiatives.

6. Summary and Recommendations for the UAE

From a sustainability perspective, a significant majority (90–95%) of energy use for all lighting products occurs in the use phase. Because fossil fuel is a major source of energy production, the majority of the environmental impacts also occur in the use phase. Incandescent light bulbs are the least energy efficient and use approximately 4 times more energy than CFLs and LEDs, respectively. Currently, the UAE produces almost all of its electrical energy through natural gas power plants.

[19] http://www.almr.org/
[20] http://www.mrtsystem.com/

Relative proportions of environmental impacts will change with changes to the sources of fuel in the electricity grid (e.g., movement to alternative and renewable energy).

As shown by our analysis of upgrade scenarios, as compared to the current baseline situation, the energy savings and associated reductions in GHG from electricity production make the implementation of high-efficiency lighting an attractive solution for the lighting sector. **Table 14** summarizes the results of our analysis.

Table 14. Summary of Emissions Savings and Mercury Pollution from Lighting Upgrades.

	GHG Emission Savings (MT CO_2-eq)	SO_x Emission Savings (MT SO_2)	NO_x Emission Savings (MT NO_x)	Particulate Matter Emission Savings (MT PM)	Mercury Pollution Savings[a] (kg/yr)
Incandescent Phase-out	861,669	18,001	4,659	41	-9
Halogen Phase-out	67,960	1,420	367	3	-1
Low-efficiency CFL Phase-out	9,139	191	49	0.4	1
Total	938,768	19,612	5,075	44	-9

[a] Applies to a CFL-based replacement strategy only.

As described in the Baseline Report, lighting usage rates used in the analysis are a significant determinant of the energy, economic, and environmental impact estimates. Our analysis uses a relatively conservative estimate based on a study conducted by the U.S. Department of Energy. For several reasons, it may underestimate residential lighting usage in the UAE, but it was selected because it provides the best documented and most defensible usage rate estimates.

An alternative source of information for residential lighting use in the UAE is provided from an informal survey that ESMA conducted with its staff in 2012. ESMA collected lighting usage information on 42 residences from a combination of National and non-National households. As shown in the Baseline Report, the reported lighting usage per day was on average 7.5 hours, which is higher than the other studies. One explanation for the relatively high usage rates is that the ESMA survey did not account for the possibility that not all the lamps in a room are on at any given time. For example, a kitchen may have 20 to 30 lamps of different types, but only about half of them may be on at any given time. Thus, if lights are on the kitchen for 6 hours, this translates into 3 hours when applied to the full set of lamps. The international studies used as the basis for the main analysis are based on actual metered usage and are able to capture these factors.

As shown in the *Assessment of Technical, Economic and Achievable Potential* memorandum (RTI, 2012b), total energy savings when using the ESMA survey is 8,123 GWhs per year. **Table 15** presents the total emission savings and mercury pollution when the ESMA usage hours and associated energy savings are applied (based on transition to CFLs). The associated social benefits are estimated to be 5.2 billion AED per year based on switching to CFLs.

Table 15. Summary of Emissions Savings and Mercury Pollution from Lighting Upgrades When ESMA Usage Hours are Applied.

	GHG Emission Savings (MT CO_2-eq)	SO_x Emission Savings (MT SO_2)	NO_x Emission Savings (MT NO_x)	Particulate Matter Emission Savings (MT PM)	Mercury Pollution Savings[a] (kg/yr)
Total	3,727,105	77,863	20,151	177	-38

[a] Applies to a CFL-based replacement strategy only. The negative estimate indicates that the mercury pollution increases with respect to the baseline estimate.

CFLs represent the most likely near-term technology for bulb upgrades. While CFLs consume less energy and have a longer lifetime, they do contain mercury, which has raised concerns that they might lead to health and environment impacts. At the time of this study, only one mercury-containing bulb-recycling operation (machine) was found in the UAE. Currently, this pilot operation is on hold, and the mercury and other materials recovered by this facility are being stockpiled until further guidance is provided by the government about proper management. The majority of lighting products are currently disposed in landfills in the UAE. Few existing landfills have modern environmental controls, such as double liners to prevent the leaching of toxic/hazardous materials (such as mercury) into the soil and groundwater. Although the mercury in a single CFL is relatively small, the large number of potential CFLs disposed translates into more significant amounts of mercury that have the potential to be released if proper end-of-life management schemes and infrastructure are not developed. Bulb breakage and mercury release is also a concern in the use phase. There are a number of resources available for proper clean-up of broken CFLs, and education campaigns would be needed to educate residents and environmental service providers. If CFLs are the upgrade of choice/policy, low-mercury CFLs would be a recommended action to minimize potential release and exposure through breakage in the use and end-of-life phases. In general, more specific human health and ecological risk assessments are needed to better inform decision makers about potential mercury-related impacts in the UAE.

It is generally thought that the public investment for substituting incandescent with high-efficiency lighting (e.g., CFL, LED) is much lower than the investment for installing more electricity generation capacity (McKinsey, 2011). Therefore, subsidizing the transition to EEL may be a more efficient investment than subsidizing increased power production (from conventional or alternative sources) from a government perspective. Replacing traditional lighting technology with EEL in turn may be a better approach for reducing CO_2 emissions than other CO_2 reduction activities. At the consumer level, EEL appear to pay for themselves in almost all applications due to their extended life and reduced energy consumption as compared to incandescent bulbs.

The results of this assessment indicate that conversion to high-efficiency residential lighting technologies has the potential to reduce the energy and associated environmental impacts while providing similar levels of luminosity. Our findings indicate that, in the current state of the technologies, high-efficiency CFLs provide the most cost-effective option to realize these environmental and energy savings, as illustrated in **Figure 13**. The x-axis in Figure 13, Cost, represents the estimated purchase costs of each lighting technology. The y- axis in Figure 13, Energy and Environmental Impact, represents the energy consumption and its highly-correlated GHG, NO_x, SO_x, and PM emissions for each lighting technology.

As demonstrated in Figure 13, high-efficiency CFL and LED lamps provide the greatest energy and environmental benefits, such as reduced GHGs, NO_x, and SO_x emissions; lower energy production costs; and decreased number of spent lamps. CFLs currently cost significantly less to implement than LED lamps at the point of purchase. However, due to the increased energy efficiency of LEDs relative to CFLs, their impact on reducing electricity consumption and cost puts them more in-line with CFLs. LFL and low-efficiency CFL lamps are also environmentally preferable to incandescents and halogens without being cost prohibitive, but demonstrate slightly less energy (and emission) savings than CFLs and LEDs.

From a cost perspective, it is important to note that despite the purchase cost of LEDs is currently significantly higher than CFLs, LEDs do not contain mercury or other toxic metals that would require special handling and end-of-life management systems. Additional costs would likely be needed for consumer outreach and education that covers the safe handling and clean-up for broken CFLs, programs and infrastructure for CFL collection and recycling or disposal, and worker training for the proper management of CFLs. These types of costs are not well characterized in the literature.

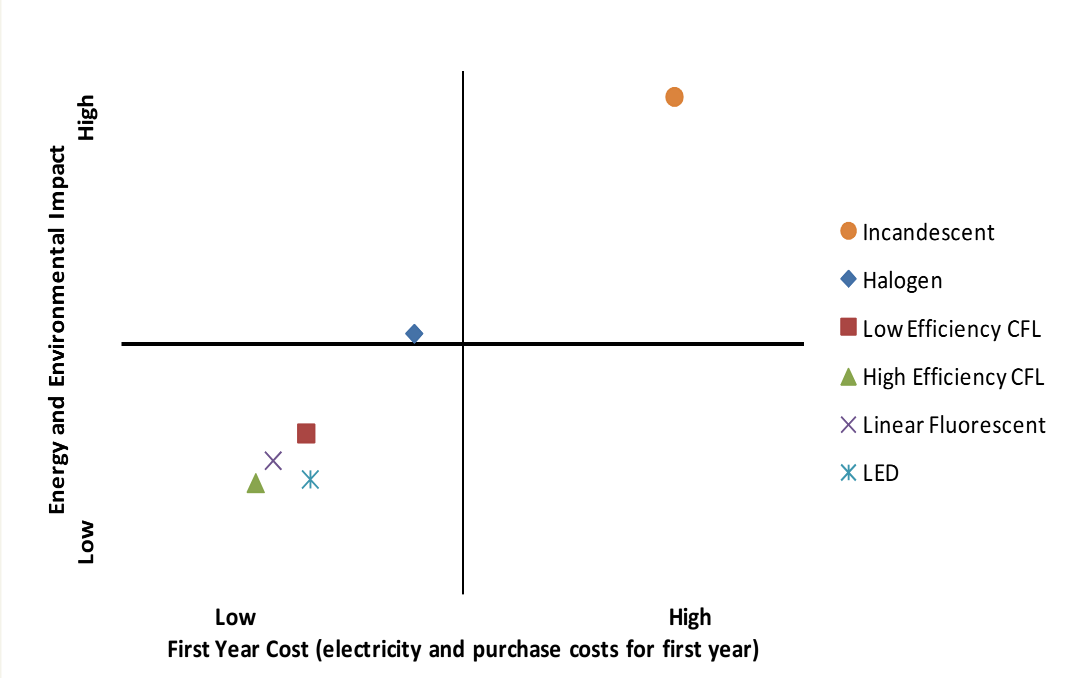

Figure 13. Boston chart illustrating the relative first year cost and potential energy and environmental impacts of each lighting technology.

In **Figure 14**, we plotted the energy (consumption) impact by lighting technology against the amount of hazardous waste generated across all life cycle stages (including raw materials extraction, manufacturing, use, and end-of-life management). As shown in Figure 14, LED lights and LFLs

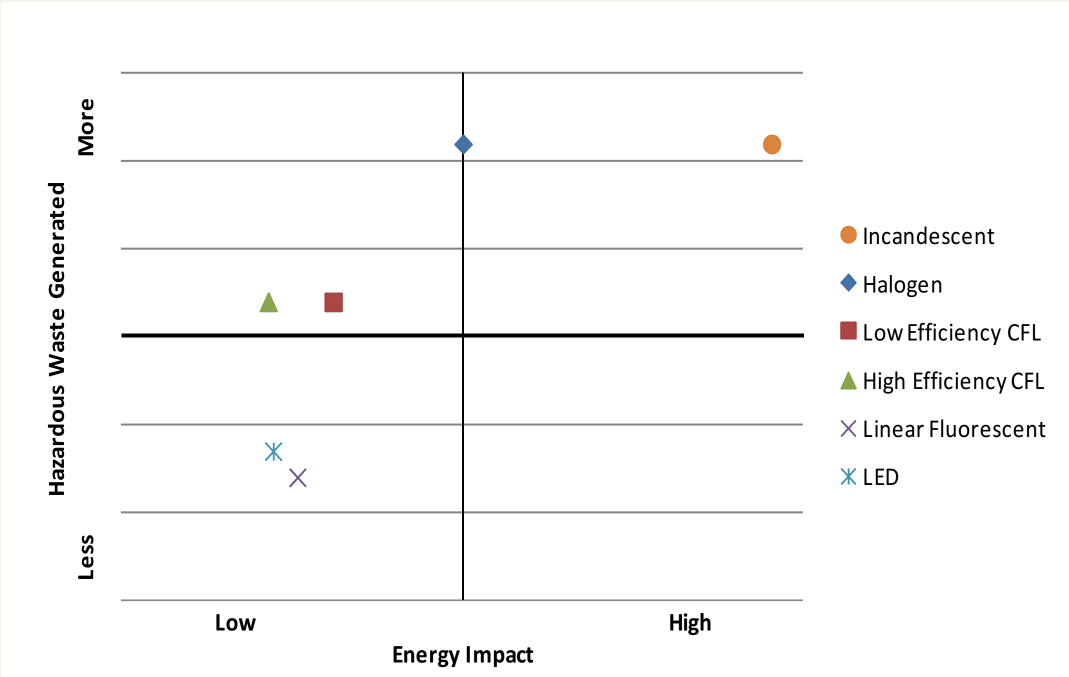

Figure 14. Boston chart illustrating the potential energy impact and hazardous waste generation of each lighting technology.

exhibit both the lowest energy impact and hazardous waste generation. CFLs show a similar energy impact as LEDs and LFLs but result in more hazardous waste generation. Halogen and incandescent bulbs exhibited the highest levels of energy impact hazardous waste generation. It is important to remember that the use stage of the lighting life cycle accounts for 90 percent or more of the total life cycle energy consumption. The replacement of inefficient lighting with EEL significantly reduces energy consumption. In addition, the production of electricity, including the extraction and combustion of fossil fuels, also generates hazardous waste. Therefore, any reduction in energy consumption has a direct impact on the reduction of hazardous waste generated.

Recommendations for UAE

From RTI's analysis of EEL, it's clear that CFLs and LEDs represent a preferred near-term lighting upgrade technology on the basis of significant reductions in energy consumption and subsequent GHG emissions and other air emissions. LEDs currently cost significantly more to purchase but CFLs contain mercury and their universal adoption in the UAE would introduce a new source of mercury that would require potentially costly programs for outreach, training, and management. If a CFL-based EEL program is adopted, it is recommended that information on what to do if a lamp breaks be available to the public and the use of low mercury-containing bulbs through programs or regulations and/or implement lamp recycling programs be promoted (NZ MfE, 2012; U.S. EPA, 2009; VITO, 2009). International best practice for end-of-life management of mercury-containing bulbs is a likely a mix of recycling programs (e.g., municipal recycling, retail take-back, manufacturer mail-in return packs).

In the forthcoming *Policy and Regulatory Framework* memorandum, RTI will detail the policy and regulatory framework and implementation options for the UAE. From a sustainability impact assessment point of view, potential recommendations for the UAE context include the following:

- Establish EEL product standards with respect to mercury contents and contents of any other hazardous substances. For CFLs, a limit of 2 mg of mercury per lamp has precedent in other countries and can be achieved without detracting from lamp performance. This will reduce the risk of residents and worker exposure to mercury in the case of CFL breakage. An alternative to a fixed mercury content limit is a lamp-specific limit that is phased in, such as that of the European Union, as shown in **Table 16**.

Table 16. Maximum Mercury Content Limits in the European Union for CFLs.

CFL Wattage	Maximum Mercury Content	Dates of Applicability
< 30 W	5 mg	Expired December 31, 2011
	3.5 mg	After December 31, 2011 until December 31, 2012
	2.5 mg	After December 31, 2012
≥ 30 W and < 50 W	5 mg	Expired December 31, 2011
	3.5 mg	After December 31, 2012
≥ 50 W and < 150 W	5 mg	Not included in Directive
≥ 150 W	15 mg	Not included in Directive

Source: European Parliament and of the Council, 2011.

- Since the main exposure method of mercury during CFL and LFL manufacturing is likely to be inhaled toxic dust and fumes from mercury use without adequate protective clothing or masks, require that fluorescent bulb manufacturing facilities in the UAE adopt adequate measures for worker health and safety.

- Evaluate consumer campaigns for promoting the switch to EEL and addressing potential concerns such as the high purchase cost for LEDs and potential mercury impacts associated with CFLs. Consider phasing in any mandated requirements for EEL to allow consumers time to adjust. The governments of UAE should examine subsidizing the high purchase cost for LEDs, or providing them for free. The savings in terms of energy subsidy savings and elimination of the need for costly programs and infrastructure to safety manage spent CFLs may outweigh the cost for LEDs.

- Continue work with the ESMA Sustainability Committee to develop or adopt guidance from international best practices for cleaning up broken mercury-containing lamps in the household, as well as for the safe collection, transport, storage, and disposal or recycling of spent mercury-containing lamps. For example, UNEP's en.lighten toolkit contains guidance on the safe management of mercury containing lamps[21].

- Continue work with the ESMA Sustainability Committee to develop effective end-of-life management strategies for spent bulbs, particularly mercury-containing bulbs. Encourage the implementation of modern sanitary landfills with liner systems to prevent mercury and other toxic substances from entering the soil. This is consistent with the Basel Convention and overall environmental protection legislation, as governed by UAE Federal Law No. 24 and implemented by Cabinet Order No. 37. Establish recycling programs and infrastructure for spent CFLs and LFLs. The effects of a mandatory recycling law (or conversely, a landfill disposal ban) may have differing impacts on the various populations across the different Emirates. At this time, it is difficult to estimate what the costs may be per bulb recycled. Specific program designs (as summarized in **Section 4.3.3**) would need to be defined, and detailed financial and environmental/health risk analyses conducted. Given current gaps in waste recycling throughout the UAE, we recommend that retail take-back and/or reverse vending machine type systems be established. Since the governments' electricity subsidy reduction associated with EEL adoption would be significant, at an estimated 722 million AED, this savings could be utilized to support spent mercury-containing bulb programs and infrastructure, notably:
    1) *Collection* of spent bulbs from household consumers by establishing take-back centers and reverse vending machines or through residential collection programs conducted by certified environmental service providers.
    2) *Recycling* (crushing) of bulbs at designated locations with appropriate crushing and materials separation and containment machines. Markets for the reuse and recycling of collected materials would also need to be established.
    3) *Safe disposal* of hazardous waste in landfills with appropriately constructed (e.g., double liners) and operated facilities.

- ERP programs should also be examined that require, in particular mercury-containing lamp, manufacturers to take responsibility for the post-consumer stage of lamps. Manufacturers could be required to provide information to consumers, through websites or other forms of outreach, on how and where recycling opportunities exist in the UAE.

Lastly, the social, environmental, and economic impacts of lighting technologies should be re-evaluated over time, particularly since the first generation of high-efficiency CFLs are currently nearing replacement. If LED prices decline, these lamps may become less cost-prohibitive and potentially more attractive as a phase-in technology. Additionally, other technologies may have emerged that require further investigation and evaluation in comparison to high-efficiency CFLs.

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TECHNICAL MEMORANDUM 4

POLICY AND REGULATORY FRAMEWORK

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LIST OF ABBREVIATIONS

AED........Arab Emirates Dirham
AGEDI........Abu Dhabi Global Environmental Data Initiative
CDM........Clean Development Mechanism
CFL........Compact fluorescent lamp
CO_2........Carbon dioxide
CSRO........Collection and recycling serviceorganization
DSM........Demand-side management
EAD........Environment Agency – AbuDhabi
ECAS........Emirates Conformity Assessment Scheme
EEI........Energy Efficiency Index
EEL........Energy-efficient lighting
EF........Ecological Footprint
EFI........Ecological Footprint Initiative
EPR........Extended Producer Responsibility
ESMA........Emirates Authority forStandardization and Metrology
EU........European Union
EWS-WWF........Emirates Wildlife Society, in association with the World Wide Fund for Nature
GCC........Gulf Cooperation Council
GFN........Global Footprint Network
GHG........Greenhouse gas
GWh........Gigawatts per hour
LED........Light-emitting diode
LFL........Linear fluorescent lamp
LVE........Low Voltage Equipment
MELA........Middle East Lighting Association
MEPS........Minimum Efficiency Performance Standard
MoEW........Ministry of Environment and Water
NO_x........Nitrogen oxides
PM........particulate matter
SO_x........Sulfur oxides
UAE........United Arab Emirates
USD........U.S. dollar
UNEP........United National Environmental Programme
WEEE........Waste electrical and electronic equipment

1. Introduction

This report, *Policy and Regulatory Framework*, is the final component of an overall study, Development of Lighting Standards for the United Arab Emirates, to establish the basis and recommendations for developing residential lighting standards for the United Arab Emirates (UAE). ***Section 1.1*** explains the background and purpose of the overall study, and ***Section 1.2*** includes a description of the tasks being conducted. ***Section 1.3*** contains an overview of the three companion technical reports that provided the baseline, sustainability, and economic analysis. Note, this report does not recommend which specific organizations within the UAE should assume specific roles and responsibilities. However, as part of the stakeholder engagements, discussions were held as to which organizations should lead specific activities.

Previous findings presented in the *Development of Lighting Standards for the United Arab Emirates – Baseline Assessment* report (RTI, 2012a) and the *Assessment of Technical, Economic, and Achievable Potential* report (RTI, 2012b) (henceforth referred to as the Baseline Assessment and Economic Assessment reports, respectively) estimate that residential lighting in the UAE consumes 2,446 gigawatts per hour (GWh) per year of electricity, and that over two-thirds of this energy use could be saved by transitioning to energy efficient lighting (EEL). In addition, EEL would decrease air conditioning energy consumption. The *Development of Lighting Standards for the United Arab Emirates – Sustainability Impact Assessment (SIA)* report (RTI, 2012c), henceforth referred to as the Sustainability Impact Assessment report, discusses how the environmental benefits and costs associated with the transition to primarily compact fluorescent lamps (CFLs) —i.e., reducing greenhouse gas (GHG) and other air pollutants from reduced electricity generation—come with the cost of increased hazardous waste that must be managed.

This report discusses the policy and regulatory framework needed to achieve the energy savings and environmental benefits while mitigating negative environmental impacts. The remainder of ***Section 1*** describes all the components of the study and the organization of this specific report.

1.1 Background and Purpose

The UAE has one of the highest per-capita carbon footprints in the world and a growing gap between demand and supply of energy (WWF, 2012). In combination with being a rapidly developing country and growing population, the UAE is facing an urgent need to evaluate and establish standards for reducing energy consumption in all sectors, including the residential sector, in a manner that is protective of the environment and of the country's economic and social well-being.

In 2007, the UAE's Ecological Footprint Initiative (EFI) was established through a partnership with the Ministry of Environment and Water (MoEW); the Environment Agency – Abu Dhabi (EAD);[1] the Emirates Wildlife Society, in association with the World Wide Fund for Nature (EWS-WWF); the Global Footprint Network (GFN); and more recently, the Emirates Authority for Standardization and Metrology (ESMA) to manage its Ecological Footprint (EF) through research, policy, and practice. The knowledge gained from the EFI has benefited the country by creating opportunities for UAE government leaders and residents to move towards sustainable development.

The EFI continues to tackle the country's EF and began a new phase of work in 2012. Included in this scope of work is research to support ESMA in the development of an EEL standard and labeling system for the UAE's residential sector.

The objective of the standard is to reduce energy consumption and carbon emissions while minimizing negative impacts on the UAE economy, environment, and human health. To this end, it is very important to understand the economic, environmental, health, and social implications for residents and for businesses and governmental agencies.

[1] EAD was represented by its subsidiary body, the Abu Dhabi Global Environmental Data Initiative (AGEDI).

The residential sector was selected as the focus of this study for several reasons. First, the findings of the EFI—that households account for approximately 57% of consumption for the UAE—establish the residential sector as a clear target for improving energy efficiency. In addition, lighting accounts for a significant percentage of electricity consumption in the residential sector, with energy savings potential second only to air conditioning. Residential lighting historically has been provided mostly through the use of incandescent lamps, which are the least efficient of the lighting technologies currently in the market. In contrast, lighting in the commercial, institutional (governmental and public), and industrial sectors is predominantly provided by linear fluorescent lamps (LFLs), which are among the most efficient of lighting technologies. Compared to the residential sector, these other sectors also tend to be more conscious of energy efficiency and the cost of inefficiency, particularly when there is a financial incentive, as is the case for the commercial and industrial sectors. Furthermore, implementing energy efficiency is easier in these other sectors, where selection of lighting technologies can be made through company or institutional policy decisions, rather than the personal preferences of villa or apartment residents. Finally, if the savings that can be achieved through residential lighting standards can be demonstrated to be material and economical, it stands to reason that lighting standards for other sectors would be likewise.

The decision was made to focus on the carbon component because it accounts for 80% of the country's EF. Depending on location, lighting can account for as much as 20% of the electricity consumed by the residential sector globally (IEA, 2006); thus, an increased emphasis is being placed on establishing EEL and associated policy measures. Lighting also has an impact on cooling load because it can generate heat nearly equal to the number of watts consumed. Cooling is the largest electricity-consuming activity in the UAE.

The UAE has the necessary institutional capacity to also develop such a standard, as evidenced by the labeling system for room air conditioners developed by ESMA for the UAE. With an increased emphasis being put on demand-side management (DSM) measures to address the growing gap between demand and supply of energy in the UAE, ESMA and EWS-WWF are seeking to develop a robust energy-efficiency standard, labeling system, and policy framework for lighting in the UAE's residential sector. This standard can then be expanded to cover public and private sectors as the country gains additional experience and stakeholder support, and later expanded into the remaining GCC countries.

1.2 Description of Overall Study

Figure 1 depicts the six tasks that comprise the Development of Lighting Standards for the United Arab Emirates study.

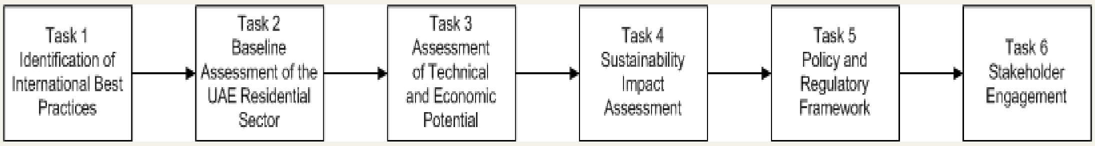


Figure 1. Flow Chart for Development of Lighting Standards for the United Arab Emirates

An overview of each task is presented below:

- **Task 1** consists of a review of international best practices. The best practices review is used to benchmark, identify possible options, and provide a template for the lighting standard developed for the UAE.
- **Task 2** is the baseline assessment of the residential sector in the UAE and includes a profile of the residential lighting sector and an estimate of electricity consumption for residential lighting in the baseline year (see RTI, 2012a).
- **Task 3** consists of an assessment of the technical and economic potential for identified lighting standards. The goal of this assessment is to ensure that the policy or standard is

within an acceptable range of cost and benefit in terms of energy savings potential, carbon savings potential, environmental and health trade-offs, recycling, and financial impacts.

- **Task 4** encompasses a sustainability impact assessment, which is a strategic tool to prevent or minimize adverse impacts to current and future generations (see RTI, 2012b). This assessment covers several areas, including recycling of spent lighting products, mercury waste generation and fate, life-cycle material assessment, cost to consumers, human health effects, public perception, and energy and carbon savings.
- **Task 5** uses the data gathered from the first four tasks (i.e., international best practices, current residential lighting usage, cost-benefit analysis, and environmental impact analysis) to advise stakeholders of policy goals and framework recommendations that will support the reduction of the UAE's carbon footprint. The outcome of Task 5 includes identification of the activities, capabilities, and regulatory frameworks needed for the successful implementation of lighting standards for the UAE. These will range from educational (e.g., workshops and stakeholder engagement) to enforcement (e.g., establishing compliance monitoring, verification, and enforcement programs).
- **Task 6** focuses on stakeholder engagement. This task is a key component of each of the prior tasks because the success of the study can only be assured if key decision makers across the government and the private and residential sectors are involved throughout the standard development process.

1.3 Stakeholder Engagement and use of the Technical Reports

A series of reports were generated as a result of Tasks 2, 3, and 4, outlined above, which contain the technical details of the analysis. These reports were distributed to the Performance and Safety Standards Committee, Sustainability Committee, Market Monitoring Committee, and other key stakeholders for comments. The committees were organized to guide the standards development process and provide a forum for input from experts and interested parties. Committee members provided both written comments and oral feedback at a series of meetings and workshops held in Dubai. The committee members include:

- ADDC
- ADM
- ADWEA
- Bee'ah
- DEWA
- Dubai Municipality
- EAD
- ESMA
- EWS-WWF
- FEWA
- GAL Lighting
- MASDAR City
- MELA
- MOEW
- OSRAM AG
- OSRAM Middle East
- Philips Lighting Middle East
- RSB
- RSB-AD
- SWEA
- Sharjah Municipality
- Tridonic Middle East FZE
- UPC

Initial versions of the reports were distributed to all stakeholders for comments. The findings were then presented at a series of committee meetings, as shown below:

- *Overview of Baseline, Technical, and Economic Analysis*. Presented to the Performance and Safety Standards Committee at the Committee Meeting for the Development of UAE Regulation for Lighting Products, 17 September 2012.
- *Review of Baseline, Technical, and Economic Analysis*. Presented to the Market Surveillance and Enforcement Technical Committee at the Committee Meeting for the Development of UAE Regulation for Lighting Products, 18 September 2012.
- *Overview of Sustainability Impact Assessment.* Presented to the Sustainability Technical committee at the Committee Meeting for the Development of UAE Regulation for Lighting Products, 19 September 2012.

Stakeholder comments were incorporated and addressed, and final versions of the reports have been distributed and are available upon request. The reports and presentations provided a framework for discussion at the committee meetings and included a review of relevant European Union (EU) laws and directives. The reports also highlighted issues to be considered when developing the regulation and quantified the economic and environmental benefits and costs. Input and feedback were received from agencies throughout the UAE and from industry.

Separate meetings were held with representatives of the Middle East Lighting Association (MELA) to receive and address industry comments. MELA is an international trade association made up of lighting suppliers that serve the Middle East. MELA members provided information on lamp sales in the UAE by lamp type and provided comments on technical assumptions used in the technical potential, sustainability, and economic analysis. MELA members include

1. GE
2. Osram
3. Philips Lighting
4. Havells-Sylvania
5. Tridonic
6. Zumbotel.

1.4 Key Research Results

The following is a summary of each of the technical reports.

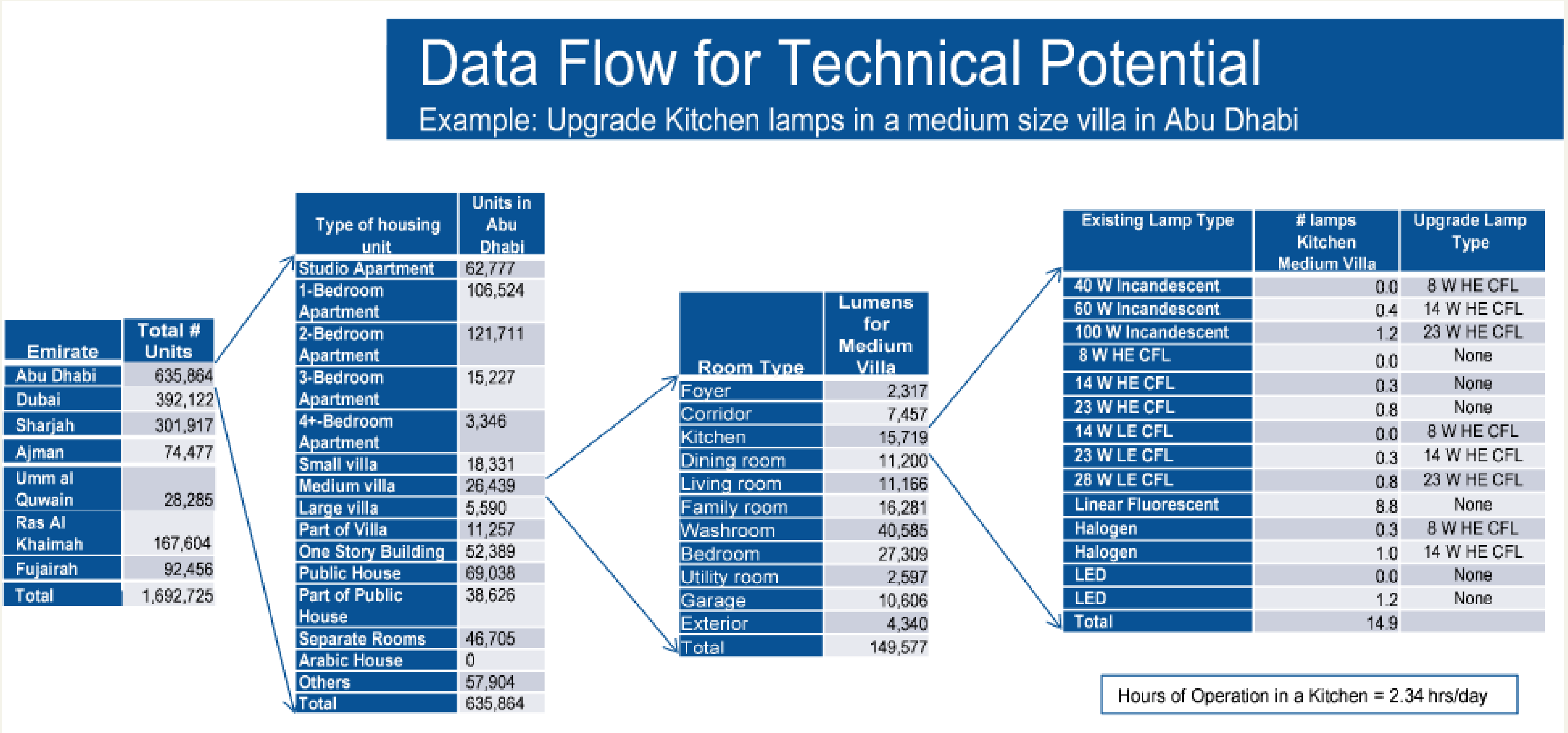
1.4.1 Baseline Analysis

This section provides a summary of lighting stock baseline in the UAE. A detailed list of data sources and assumptions used in developing the baseline are presented in the Baseline Assessment report (RTI, 2012a). An overview of how the baseline lighting stock was developed is as follows:

- The number of residential housing units was obtained from the 2005 Census and projected to 2011 using population growth estimates.
- The distribution of housing unit type was obtained from the 2005 Census and is assumed to be constant over time within each Emirate.
- Each type of housing unit is defined in terms of up to 11 room types, based on typical floor plans obtained from real estate and property management companies in the UAE. Each room type (by housing type) has a size (square meters) and an illuminance requirement (measured as lux) that yields a lumens requirement.
- The typical lamp types in a room are then used in conjunction with the lumens requirement to estimate the total number of lamps and the distribution of lamp types within each room. Individual lamps are summed across room types, housing unit types, and Emirates to estimate baseline lighting usage.
- Once the number of individual lamps is determined, hours of operation by room type are used to calculate lighting energy consumption.

Figure 2 illustrates the data flow for estimating the number of lamps in a typical kitchen in a medium-sized villa. The lumen requirement for each room is first determined, and then the number of lamps needed to meet this requirement (given the distribution of lamps types within a room) is calculated. Note, in the analysis, the distribution of lamp types within a room type is the same across all types of housing units. The number of lamps differs because the size of the rooms (and hence, the lumen requirement) varies across the type of housing units. Also, the room sizes for housing unit types are constant across all Emirates, but the distribution (number) of housing unit types varies across the Emirates.

Data on lamp technology usage in the UAE were taken from a Voluntary Lighting Survey conducted as part of this study. As described in the Baseline Assessment report, data on the number of lamps by technology and room type were taken from those survey responses that were complete and internally consistent, and those data were used as the starting point. The data were then adjusted to fill in gaps for all room types and to achieve the target distribution of lamp technologies. Once the final distribution was determined, illuminance criteria obtained from international studies were then applied to the relative percentages of each lamp type to determine the specific numbers of lamps by technology, rating, and room type.



Data Flow for Technical Potential

Example: Upgrade Kitchen lamps in a medium size villa in Abu Dhabi

Emirate	Total # Units
Abu Dhabi	635,864
Dubai	392,122
Sharjah	301,917
Ajman	74,477
Umm al Quwain	28,285
Ras Al Khaimah	167,604
Fujairah	92,456
Total	1,692,725

Type of housing unit	Units in Abu Dhabi
Studio Apartment	62,777
1-Bedroom Apartment	106,524
2-Bedroom Apartment	121,711
3-Bedroom Apartment	15,227
4+-Bedroom Apartment	3,346
Small villa	18,331
Medium villa	26,439
Large villa	5,590
Part of Villa	11,257
One Story Building	52,389
Public House	69,038
Part of Public House	38,626
Separate Rooms	46,705
Arabic House	0
Others	57,904
Total	635,864

Room Type	Lumens for Medium Villa
Foyer	2,317
Corridor	7,457
Kitchen	15,719
Dining room	11,200
Living room	11,166
Family room	16,281
Washroom	40,585
Bedroom	27,309
Utility room	2,597
Garage	10,606
Exterior	4,340
Total	149,577

Existing Lamp Type	# lamps Kitchen Medium Villa	Upgrade Lamp Type
40 W Incandescent	0.0	8 W HE CFL
60 W Incandescent	0.4	14 W HE CFL
100 W Incandescent	1.2	23 W HE CFL
8 W HE CFL	0.0	None
14 W HE CFL	0.3	None
23 W HE CFL	0.8	None
14 W LE CFL	0.0	8 W HE CFL
23 W LE CFL	0.3	14 W HE CFL
28 W LE CFL	0.8	23 W HE CFL
Linear Fluorescent	8.8	None
Halogen	0.3	8 W HE CFL
Halogen	1.0	14 W HE CFL
LED	0.0	None
LED	1.2	None
Total	14.9	

Hours of Operation in a Kitchen = 2.34 hrs/day

Figure 2. Data Flow for Lighting Baseline

Figures 3 through 5 summarize the results from the baseline analysis. Baseline lighting energy usage is estimated to be 2,446 GWh per year, which is 6% of residential consumption and approximately 3.4% of total electricity consumption in the UAE. As shown in Figure 3, Abu Dhabi is the largest lighting consumer in the UAE, accounting for 35% of usage, followed Dubai and Sharjah, with 25% and 15%, respectively. The remaining Emirates account for approximately 25% of the baseline lighting energy usage.

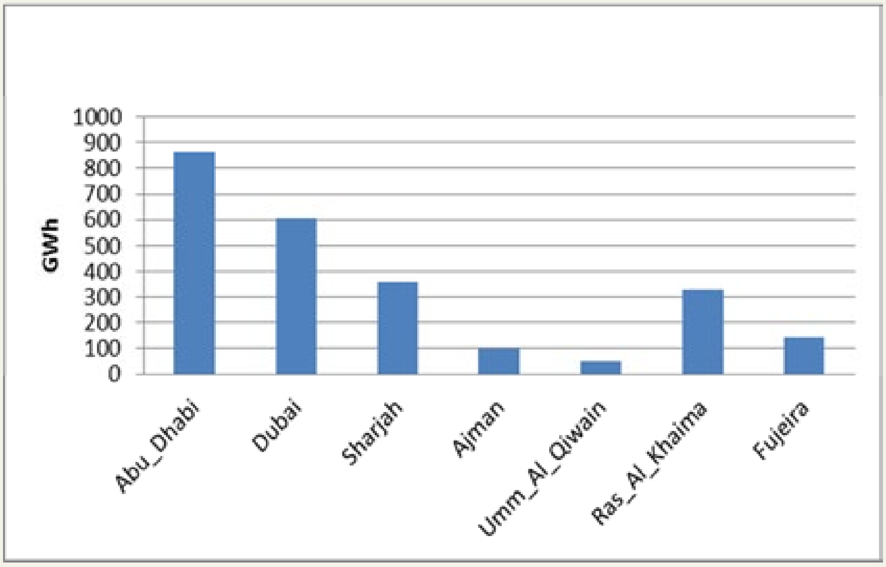


Figure 3. Baseline Residential Lighting Energy Use by Emirate across the UAE.

Villas account for the largest share of lighting energy usage, totaling 36% (see Figure 4). The majority of the consumption is associated with medium-sized villas. Public houses and Arabic Houses (similar to villas) account for an additional approximately 20%. Apartments account for 30% of lighting energy usage in the UAE, with the majority of usage attributed to two-bedroom and one-bedroom apartments.

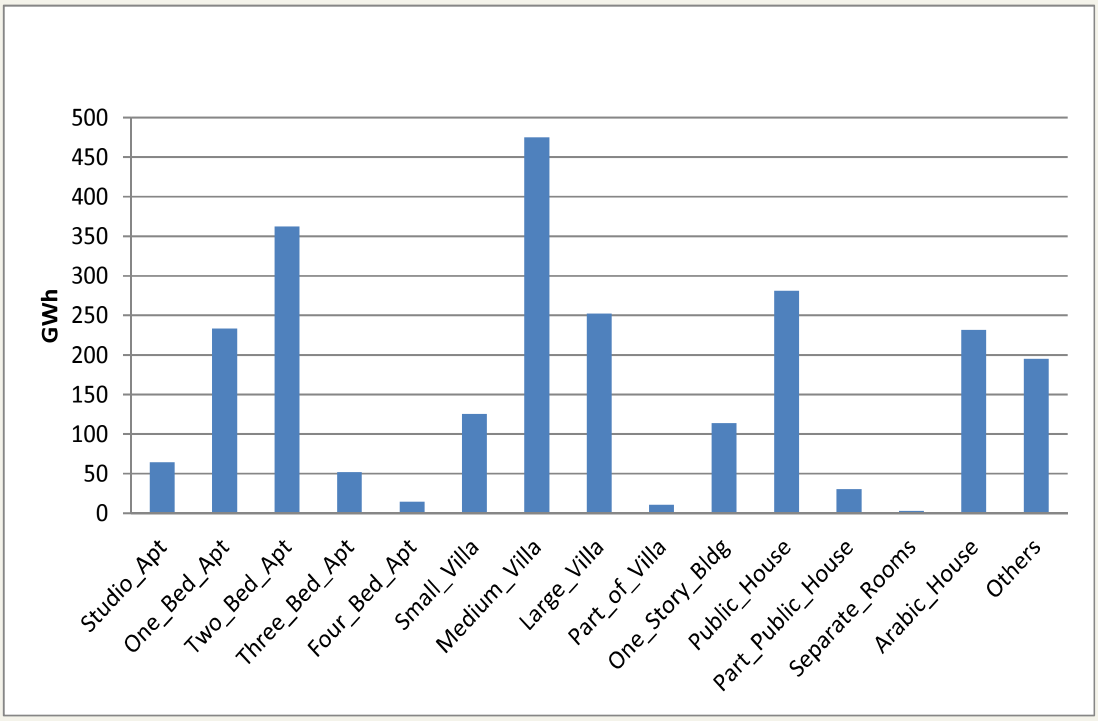


Figure 4. Baseline Residential Lighting Energy Use by Housing Type across the UAE.

Figure 5 shows the breakdown of the different incandescent, CFL, halogen, LFL, and light-emitting diode (LED) lighting technologies based on electricity consumption. Incandescent lamps account for the overwhelming majority of lighting energy usage, totaling 78%. Within the incandescents, 60-watt lamps represent the bulk of the energy consumption. CFLs account for approximately 8% of the lighting energy consumption, with 14-watt CFLs (the equivalent of a 60-watt incandescent) representing the largest share. LFLs and halogens account for approximately 7% each, with minimal penetration of LEDs.

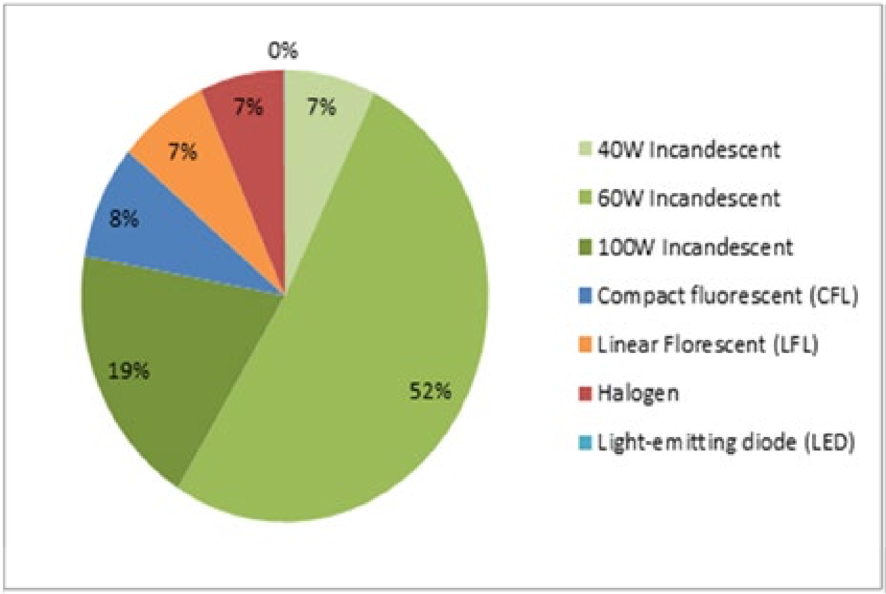


Figure 5. Baseline Residential Energy Use by Lighting Technology across the UAE.

1.4.2 Technical and Economic Potential Analysis

This section presents an overview of the Economic Assessment report (RTI, 2012b). To support the economic analysis, the modeling framework illustrated in Figure 2 was operationalized in a computer model programed in the GAMS software. The model is essentially a multidimensional linear program that accounts for every lamp in the UAE. Each lamp in the baseline is assigned a series of attributes that determine its location and tariff rate, operating characteristics (hours/year), energy consumption (watts), price (Arab Emirates Dirham [AED]), life expectancy (hours), and potential for EEL upgrade. Based on these characteristics, the model can calculate the electricity savings under different lighting upgrade scenarios.

The annual technical potential for energy savings by switching to EELs is estimated to be 2,046 GWh based on the 2011 UAE population. This represents a 5% reduction in residential energy consumption and a 2.9% reduction in total UAE electricity consumption. The savings are comprised of a 65% reduction in direct indoor residential lighting electricity use and a 28% cooling bonus due to reduced air conditioning demand. The cooling bonus reflects reducing air conditioning use associated with avoided heat produced by incandescent lamps, and further reducing natural gas consumptions for power generation and its associated GHG emissions.

The elimination of incandescent lamps with CFLs accounts for 92% of the savings. The elimination of halogen lamps accounts for 7% of savings, and the elimination of low-efficiency CFLs from the market accounts for the remaining 1% of savings. The incremental savings potential for each technology type is presented in **Table 1** for each Emirate. As can be seen, the overwhelming majority of the savings are realized in the phase-out of incandescent lamps. The phase-out of halogens and low-efficiency CFLs represent a relatively small savings potential due to their current low market share.

Table 1. Annual Energy Savings by Technology Phase-Out (GWh)

	Incandescents	Halogens	Low-efficiency CFLs	Total
Abu Dhabi	656.4	56.1	7.1	719.5
Dubai	463.8	36.4	4.9	505.1
Sharjah	273.5	22.6	2.9	299.0
Ajman	75.4	6.1	0.8	82.2
Umm Al Qiwain	40.4	2.9	0.4	43.8
Ras Al Khaima	254.8	18.2	2.7	276.0
Fujeira	111.2	8.5	1.2	120.8
Total	**1,875.5**	**151.0**	**19.9**	**2,046.4**

All of the EEL options modeled were found to be economically viable in that the reduction in electric bills to households more than offset the incremental cost of the EELs. In general, CFLs were cost-effective due the combination of lower energy consumption and longer life expectancy. It is recommended that both of these parameters be confirmed under UAE operating conditions through testing and monitoring because of their potential to impact the economic analysis.

Total social benefits are estimated to be approximately 668 million AED per year after full adoption of EELs. The household sector benefits are estimated to be 459 million AED per year after full adoption of EELs. Households in Dubai realize the largest share of benefits because they face the highest tariff rate across Emirates. In addition to household benefits, subsidy reductions to the government are estimated to be 216 million AED per year. Abu Dhabi realizes the greatest subsidy reductions because it has the lowest tariff rates. Note that the economic analysis does not include some additional social costs (such as disposal and recycling) or ancillary social benefits (reduced GHG emissions). In addition, some government investment will need to be made, such as educating populations on the benefits and enforcing import restrictions. The policy instruments that need to be put in place will be discussed in the remainder of this Policy and Regulatory Framework report.

The economic benefits to households and governments are primarily associated with the phase-out of incandescents. **Table 2** shows the incremental savings/benefits associated with each technology phased out.

Table 2. Incremental Annual Social Benefit by Technologies Phase-Out (1,000 AED)

Technologies Phased Out	Total Annual Energy Savings (GWH)	Annual Increase in Lamp Expenditures (a)	Annual Household Savings from Reduced Electricity Bills (b)	Annual Government Savings from Subsidy Reduction (c)	Full Annual Social Benefits (b+c-a)
Incandescents	1,875	2,268	420,840	198,072	616,644
Halogens	151	3,097	33,967	15,868	46,738
Low-efficiency CFLs	20	2,048	4,473	2,104	4,530
Total	**2,046**	**7,413**	**459,280**	**216,044**	**667,911**

The achievable potential (i.e., savings actually realized) is likely to be very high given the implementation approach of codes and standards being proposed. Import bans on low-efficiency products are a very effective way to transform the market and achieve the majority of the technical potential; however, a smooth supply chain transition is key for achieving benefits in the short run, and enforcement is essential for achieving benefits in the long run.

1.4.3 Sustainability Analysis

This section presents an overview of the Sustainability Impact Assessment report (RTI, 2012c). From a sustainability perspective, a significant majority (90–95%) of energy use for all lighting products occurs in the use phase. Because fossil fuel is a major source of energy production, the majority of the environmental impacts also occur in the use phase. Incandescent light bulbs are the least energy-efficient and use approximately four times more energy than CFLs and LEDs. Currently, the UAE produces almost all of its electrical energy through natural gas power plants. Relative proportions of environmental impacts will change with changes to the sources of fuel in the electricity grid (e.g., movement to alternative and renewable energy).

As compared to the current baseline situation, the energy savings and associated reductions in GHGs from electricity production make the implementation of high-efficiency lighting an attractive solution for the lighting sector. **Table 3** summarizes the results of the analysis.

Table 3. Summary of Emissions Savings and Mercury Pollution from Lighting Upgrades

	GHG Emission Savings (MT CO_2-eq)	SO_x Emission Savings (MT SO_2)	NO_x Emission Savings (MT NO_x)	Particulate Matter Emission Savings (MT PM)	Mercury Pollution Savings[a] (kg/yr)
Incandescent Phase-out	861,669	18,001	4,659	41	-9
Halogen Phase-out	67,960	1,420	367	3	-1
Low-efficiency CFL Phase-out	9,139	191	49	0.4	1
Total	**938,768**	**19,612**	**5,075**	**44**	**-9**

[a] Applies to a CFL-based replacement strategy only.

As described in the Baseline Assessment report, lighting usage rates used in the analysis are a significant determinant of the energy, economic, and environmental impact estimates. Our analysis uses a relatively conservative estimate of approximately 2 hours per day based on a study conducted by the U.S. Department of Energy. For several reasons, it may underestimate residential lighting usage in the UAE, but it was selected because it provides the best documented and most defensible usage rate estimates.

An alternative source of information for residential lighting use in the UAE is provided from an informal survey that ESMA conducted with its staff in 2012. ESMA collected lighting usage information on 42 residences from a combination of National and non-National households. As shown in the Baseline Assessment report, the reported lighting usage per day was on average 7.5 hours, which is higher than the other studies. The electricity saving increases approximately four fold, to 8,138 GWhs, when the ESMA usage hours are applied. Emissions savings (GHG, SO_x, NO_x, and PM) also increased four-fold because they are directly linked to electricity generation. Mercury pollution would increase as usage per day increases because lamp failure rates would increase.

CFLs represent the most likely near-term technology for lamp upgrades. While CFLs consume less energy and have a longer lifetime, they do contain mercury, which has raised concerns that they might lead to adverse health and environment impacts. At the time of this study, only one mercury-containing bulb-recycling operation (machine) was found in the UAE. Currently, this pilot operation is on hold, and the mercury and other materials recovered by this facility are being stockpiled until further guidance is provided by the government about proper management. The majority of lighting products are currently disposed in landfills in the UAE. Few existing landfills have modern environmental controls, such as double liners to prevent the leaching of toxic/hazardous materials (such as mercury) into the soil and groundwater. Although the mercury in a single CFL is relatively small, the large number of potential CFLs disposed translates into more significant amounts of mercury that have the potential to be released if proper end-of-life management schemes and infrastructure are not developed. Bulb breakage and mercury release is also a concern in the use phase. There are a number of resources available for proper clean-up of broken CFLs, and education campaigns would be needed to educate residents and environmental service providers. If CFLs are the upgrade of choice/policy, low-mercury CFLs would be a recommended action to minimize potential release and exposure through breakage in the use and end-of-life phases. In general, more specific human health and ecological risk assessments are needed to better inform decision makers about potential mercury-related impacts in the UAE.

It is generally thought that the public investment for substituting incandescent with high-efficiency lighting (e.g., CFL, LED) is much lower than the investment for installing more electricity generation capacity. Therefore, subsidizing the transition to EEL may be a more efficient investment than subsidizing increased power production (from conventional or alternative sources) from a government perspective. Replacing traditional lighting technology with EEL, in turn, may be a better approach for reducing carbon dioxide (CO_2) emissions than other CO_2 reduction activities. At the consumer level, EELs appear to pay for themselves in almost all applications due to their extended life and reduced energy consumption, as compared to incandescent bulbs.

The results of this assessment indicate that conversion to high-efficiency residential lighting technologies has the potential to reduce the energy and associated environmental impacts while providing similar levels of luminosity. Our findings indicate that, in the current state of the technologies, high-efficiency CFLs provide the most cost-effective option to realize these environmental and energy savings, as illustrated in **Figure 6**. The x-axis in Figure 6, *Cost*, represents the estimated purchase costs of each lighting technology. The y- axis in Figure 6, *Energy and Environmental Impact*, represents the energy consumption and its highly correlated GHG, nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM) emissions for each lighting technology.

As demonstrated in Figure 6, high-efficiency CFL and LED lamps provide the greatest energy and environmental benefits, such as reduced GHGs, NO_x, and SO_x emissions; lower energy production costs; and decreased number of spent lamps. CFLs currently cost significantly less to implement than LED lamps at the point of purchase. However, due to the increased energy efficiency of LEDs relative to CFLs, their impact on reducing electricity consumption and cost puts them more in line with CFLs. LFL and low-efficiency CFL lamps are also environmentally preferable to incandescents and halogens without being cost prohibitive, but demonstrate slightly less energy (and emission) savings than CFLs and LEDs.

From a cost perspective, it is important to note that despite the fact that the purchase cost of LEDs is currently significantly higher than CFLs, LEDs do not contain mercury or other toxic metals that would require minimal special handling and end-of-life management systems. Additional costs would likely be needed for consumer outreach and education that covers the safe handling and cleanup for broken CFLs; programs and infrastructure for CFL collection and recycling or disposal; and worker training for the proper management of CFLs. These types of costs are not well-characterized in the literature.

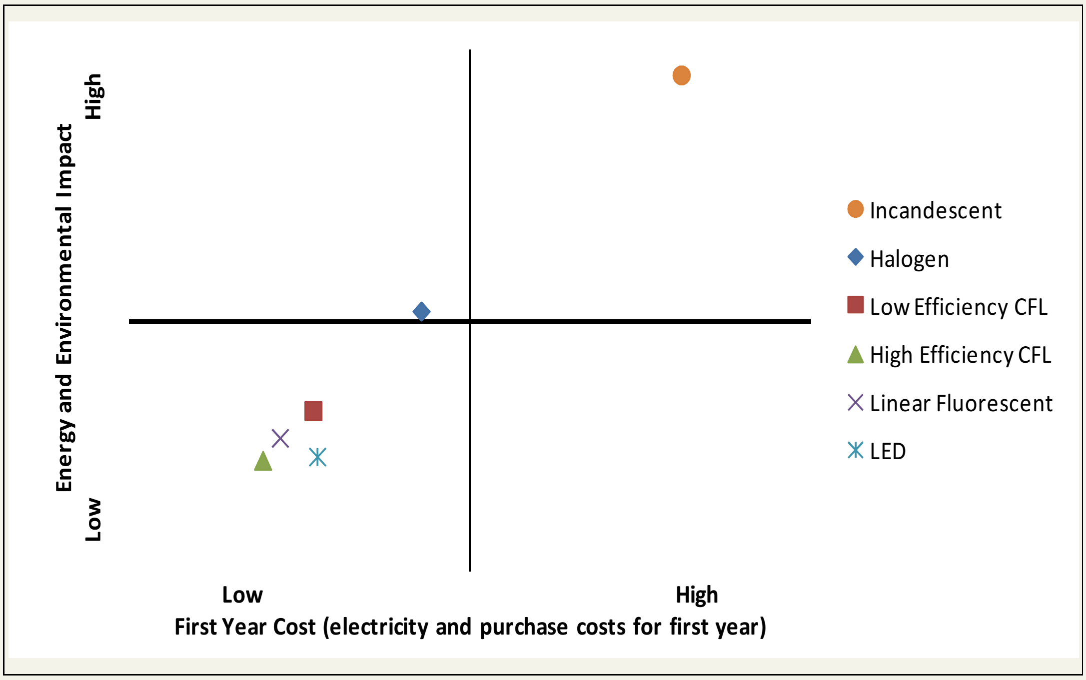


Figure 6. Boston Chart Illustrating the Relative First-Year Cost and Potential Energy and Environmental Impacts Of Each Lighting Technology.

In **Figure 7**, we plotted the energy (consumption) impact by lighting technology against the amount of hazardous waste generated across all life-cycle stages (including raw materials extraction, manufacturing, use, and end-of-life management). As shown in Figure 7, LEDs and LFLs exhibit both the low energy impact and low hazardous waste generation. LFLs are shown to have a slightly lower hazardous waste generation potential than LEDs. This is primarily due to the hazardous waste generation in the manufacturing stage of the LED life cycle.

CFLs show a similar energy impact as LEDs and LFLs, but result in more hazardous waste generation. Halogen and incandescent bulbs exhibited the highest levels of energy impact hazardous waste generation. It is important to remember that the use stage of the lighting life cycle accounts for 90% or more of the total life cycle energy consumption. The replacement of inefficient lighting with EEL significantly reduces energy consumption. In addition, the production of electricity, including the extraction and combustion of fossil fuels, also generates hazardous waste. Therefore, any reduction in energy consumption has a direct impact on the reduction of hazardous waste generated.

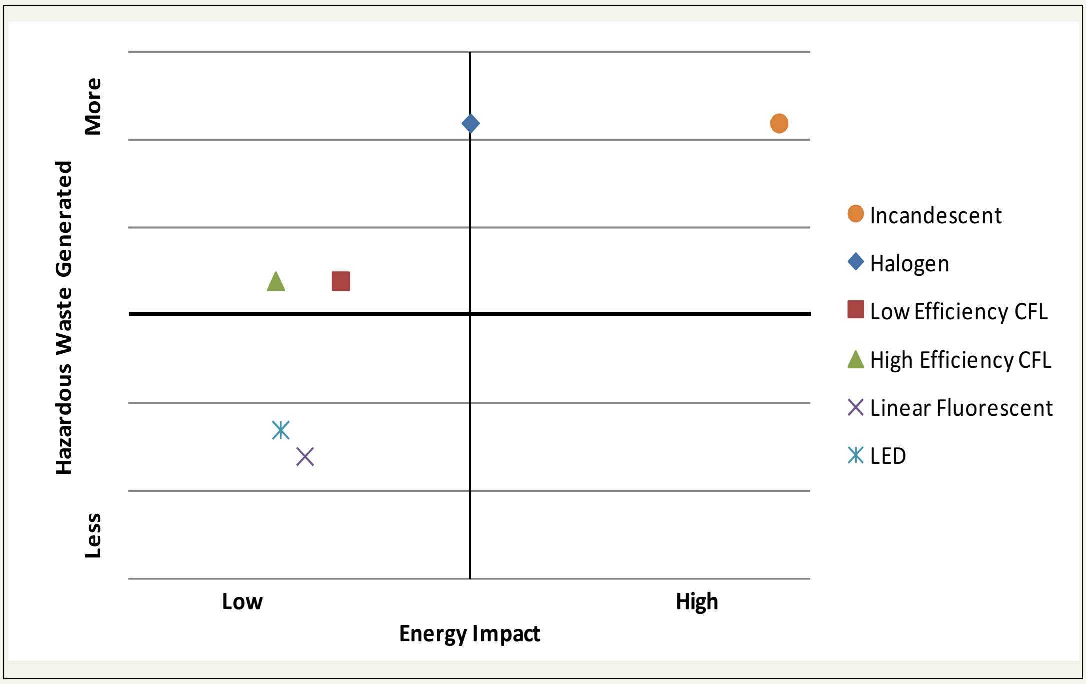


Figure 7. Boston Chart Illustrating the Potential Energy Impact and Hazardous Waste Generation of Each Lighting Technology.

2. Policy Discussion

This section discusses several topics related to the overall structure and framework of the residential lighting standard being developed. As with any government policy, the options, scope, and bounds must be well-defined prior to developing an implementation framework.

2.1 Overarching Policy Options and Scope

To capture the greatest impact in the shortest period of time, the residential lighting standard should begin by focusing on lamps, and specifically on existing incandescent and halogen lamps and the possible high-efficiency replacements for those lamps. Implementation of a residential lighting standard will rely considerably on residential consumers to replace inefficient lighting with high-efficiency lighting, and a standard that targets existing lamps is much simpler to implement than a standard that addresses a combination of lamps and fixtures.

If a fixture uses inefficient lamps, the consumer can easily replace it, in most cases, with a high-efficiency lamp. On the other hand, replacing existing fixtures, and especially built-in fixtures, requires much greater capital expenditures than replacing lamps. In terms of restricting availability in the market, it also is much easier to limit imports of lamp technologies, which are relatively few in number, than to limit the imports of fixtures. However, for new construction, the situation is quite different. Most apartments and villas include built-in fixtures, which often are LFLs, but may include halogen fixtures. Developing a standard that specifies minimum efficiencies for built-in fixtures in new construction can help ensure the use of high-efficiency lighting in the residential sector. For example, the standard could specify minimum efficiencies for fluorescent ballasts and restrict the use of halogen lighting.

Residential lighting standards that phase-out incandescent, halogen, and low-efficiency CFLs could generate significant economic benefits for the UAE and should likely be the focus of the initial standard. As shown in Table 2 and again in **Table 4**, social benefits (i.e., benefits to households and government) associated with phasing-out these three categories of inefficient lamps are estimated to be AED 668 million per year based on switching to high-efficiency CFLs. Combing these annual benefits with the initial CFL upgrade costs yields the payback period for the investment, as shown in

Table 4. The social payback period for a wholesale upgrade to CFLs would be approximately 1.1 years. This means that the full cost of switching incandescent, halogen, and low-efficiency CFLs to high-efficiency CFLs would be covered by the reduction in electricity production costs in approximately 13 months. From the government's perspective, if they were to fully fund the transition with subsidy reductions, the payback period would be approximately 3.4 years (although this would vary by Emirate because of differences in the tariff rates and, hence, subsidy reductions). Both the social and government payback periods strongly support aggressively moving forward with residential lighting standards.

LEDs also represent an attractive option with current savings and annualized costs comparable to (but both slightly less than) CFLs. However, as shown in Table 4, the price of LEDs is 5 to 7 times higher, which increases the payback period from the social and government perspective to 8.5 and 26.2 years, respectively. Wholesale upgrade to LEDs would cost over AED 5 billion. For this reason, it is anticipated that CFLs will be the dominate EEL in the market for the near future. However, as LED technology improves in terms of efficiency and price, policy makers will want to consider promoting LED adoption in the future to take advantage of their environmental benefits (e.g., less toxic metals).

Table 4. First Cost of Full Lamp Replacement and Associated Payback (AED 1,000)

	First cost replacement to CFLs	First cost replacement to LEDs
Upgrade Cost	732,704	5,659,402
Subsidy Reduction (Annual government benefits)	216,044	216,044
Government Payback (years)	3.4	26.2
Social Benefits (Annual household + government)	667,911	667,911
Social Payback (Years)	1.1	8.5

Government policies facilitating the phase-out of inefficient lamps have traditionally fallen into two broad categories: market-based programs and incentives, and technology/efficient regulations and standards. Implementation options for these policies range from rebates and other forms of subsidies to product bans and import restrictions. For the UAE, product bans and import restrictions appear to be the most attractive option for promoting EELs. Market-based solutions work poorly when electricity prices do not reflect the full cost of power generation. In addition, as shown in Table 2, a sizable share of the benefits (hence, the incentive) from switching to EELs accrue to the government in the form of electricity subsidy reduction.

With minimal domestic production of lamps and a limited number of ports of entry, an import ban would be a manageable policy option for promoting EELs. In addition, because most incandescent and halogen lamps can be easily identified by visual inspection, this lowers the cost of implementing the import ban at the port of entry and enforcing the ban throughout the supply chain (retail inspections, for example).

Poor-quality products (CFLs, LFLs, and LEDs) present a challenge for realizing the full saving potential of the residential lighting standards. It has been estimated that approximately 10–20% of CFLs on the global market are of poor to medium quality (U.S. Agency for International Development [USAID], 2007). These low-quality florescent lamps have lower efficiency (lumens/watt), shorter life expectancy, and higher levels of toxic metals. However, phasing these low-efficiency lamps out of the UAE market will be more complicated compared to simply banning incandescents. Testing and certification programs will need to be developed and implemented, and inspection, verification, and market monitoring will need to be continuously ongoing. This will require the development of programs to manage the operations and the potential training of a skilled labor force to staff these institutions/organizations.

2.2 The Need for Financial Incentives

An important question to be considered in the planning for implementing the standard will financial incentives be needed, and if so, what type. Even if a mandatory ban on families of lamp technologies is the policy option of choice, there may be valid reasons for financial incentives to accelerate adoption, increase compliance, and/or minimize the initial financial burden on households. In addition to the type and magnitude of the financial incentives, the timing should also be considered. For example, are incentives needed only to lessen the initial transition (first cost) of purchasing more expensive EELs?

A number of incentive mechanisms have been used internationally to promote EELs among residences. Programs such as rebates, giveaways, and exchanges; mark-downs; and tax deductions have been observed in the United States and Canada over the years, primarily for the sale of CFLs. However, on their own, they have been shown to be only modestly successful. For example, despite incentive programs to urge the adoption of the more efficient CFLs, the United States has observed declining sales since its peak in 2001 (Vestel, 2009). The following discussion investigates several issues related to incentive mechanisms used to promote EELs in the residential sector.

The Dubai Carbon Centre of Excellence has an ongoing CFL project working in cooperation with the Clean Development Mechanism (CDM). CDM and other carbon markets employ quantified GHG emission reduction “credits” to create a tradable commodity out of GHG emission reductions avoidance. The price for these credits reflects a specific carbon currency linked to the demand associated to a voluntary or compliance market. This type of market solution is considered to be a Public Private Partnership (or PPP) and can be an effective step forward towards a participative approach towards climate-change challenges.

2.2.1 Timing and Target of Incentive Programs

Financial incentives may only be needed for the first 2 years. As discussed in the Economic Assessment report, the economic analysis does not support the need for prolonged incentives. Once the transition to CFLs or LEDs has occurred, the number of lamps needing to be replaced each year is relatively small. Whereas incandescent bulbs have a life expectancy of approximately 1 year, CFLs and LEDs have life expectancies of approximately 10 and 45 years, respectively. In fact, the annual cost (lamp expenditures) of maintaining a household of CFLs or LEDs is actually less than a household of incandescents.

As shown in **Table 5**, 73% of incandescent lamps are expected to fail in any given year. This means that in the first year of the standard, it is likely that households will need to replace almost all of their incandescent lamps with EELs. After the first year, the burden decreases significantly because with EEL’s longer life expectancy, only a fraction of the lamps in the household will need to be replaced each year. For example, less than 10% of high-efficiency CFLs and less than 2% of LEDs are predicted to fail each year. This lowers the long-run (steady-state) annualized cost of EELs.

Table 5. Life Expectancy by Lamp Type

Lamp Technology	Life Expectancy (hours)*	Life Expectancy (years)**
Incandescent	1,000	0.9
Low-efficiency CFL	3,000	2.7
High-efficiency CFL	10,000	9.1
Linear florescent	24,000	21.9
Halogen	2,000	1.8
LED	50,000	45.7

* Sources: Lamp life expectancies were obtained from a range of sources, including the U.S. Department for

Environment, Food and Rural Affairs, 2009; U.S. Department of Energy, 2012; Limaye et al., 2009; IEA, 2006; OSRAM Opto Semiconductors GmbH, 2009; SBI Energy, 2010; and USAID, 2007.

** This table uses the assumption of 1,095 hours of operation per year (3 hours per day). Thus, life expectancy by year is calculated by dividing life expectancy by hour by 1,095.

As shown in Table 4, transition costs could range from 700 million AED to 5.6 billion AED, depending on the type of EEL (CFL versus LED). For this reason, governments may want to consider providing financial assistance, at least in the first year or two. Either a lamp rebate or exchange program would help households with the transition to EELs. Such a program may need to be centralized at the UAE level because of the varied levels of financial resources and infrastructure at the individual Emirate level. As discussed in the Economic Assessment report, reductions in electricity subsidies could help fund such programs.

Considerations should also be given to the level of financial assistance targeted at CFLs versus LEDs. Industry trends show that the price of LEDs is likely to continue to decrease, making them a more attractive EEL option. LEDs are still a developing technology, and the majority of lamp R&D activities are currently focused on lowering the cost of LEDs. In contrast, CFLs are a mature technology, and their price is predicted to be unchanged or potentially increase in the future due to worldwide shortages of key inputs. When this is combined with the environmental concerns and/or disposal costs associated with CFLs, longer-term strategies may want to focus market transformation resources (incentives and education) on LEDs. For example, the government may want to sponsor a LED lamp give-away program to provide households an opportunity to try LEDs for free. The objective being that once households experience LEDs' light quantity and longer life expectancy, they may be more willing to pay the upfront cost of the transition.

Rebate Programs

Rebates have been used to mitigate the first-cost impact from transitioning to EELs in many countries. The effectiveness of rebate programs depends on:

- Ensuring that program access is widely available to all households,
- Minimizing the level of effort required for household participation, and
- Minimizing transaction costs for government implementation of the program.

Rebates provided to retailers are one of the most cost-effective implementation strategies, as opposed to mail-in rebates for individuals or households. Centralizing the rebate processing activities with retailers leverages economies of scale and lowers the transaction costs, as well as minimizing the burden on residents. In addition, rebates could be provided directly to property management companies for residential and commercial/residential apartment buildings.

The direct cost of a program would depend on the size of the rebate offered. **Table 6** provides the direct costs associated with a 2-year rebate program covering 50% and 100% of the cost of CFLs. Rebate costs range from 400 to 800 million AED. The rebates would most likely be applicable for all CFLs purchased, including purchases to replace incandescents/halogens, as well as purchases to replace existing CFL lamps. Rebates associated with replacing existing high-efficiency CFLs is commonly referred to as the *free rider* effect because they represent payments to households that would have purchased high-efficiency CFLs in the absence of the program (they increase program costs but do not count toward energy savings). Although, as shown in Table 6, free riders associated with failure and replacement of existing high-efficiency CFLs account for only 7% of rebate costs.

Table 6. CFL Rebate and Exchange Direct Program Costs (1,000 AED)

Lamp Type	Watts	Replacement Cost (AED)	Number of Lamps (1000)	Cost of CFL 50% Rebate Program	Cost of CFL 100% Rebate Program	Cost of Incandescent and Halogen Exchange Program
Incandescent	40	13.00	7,087	46,066	92,133	92,133
Incandescent	60	14.00	31,260	218,823	437,647	437,647
Incandescent	100	22.00	7,298	80,273	160,547	160,547
High-efficiency CFL	8	13.00	1,330	1,899	3,799	
High-efficiency CFL	14	14.00	12,647	19,457	38,913	
High-efficiency CFL	23	22.00	2,064	4,991	9,981	
Low-efficiency CFL	14	13.00	235	1,130	2,259	
Low-efficiency CFL	23	14.00	2,232	11,572	23,145	
Low-efficiency CFL	28	22.00	364	2,968	5,937	
Halogen	50	14.00	1,944	15,122	30,243	30,243
Total Direct Costs*			**66,461**	**402,302**	**804,604**	**720,570**

Note: Costs do not include program implementation costs. All incandescents and halogens are assumed to fail with in the 2-year program period. Life expectancy is used to calculate the share of existing high-efficiency and low-efficiency CFLs that will fail in the 2-year period. Linear fluorescent and LED lamps in this scenario are not eligible for rebates.

Table 7 presents the same rebate program scenarios for transitioning to all LEDs. Program costs are significantly higher reflecting the higher price of LEDs compared to CFLS.

Table 7. LED Rebate and Exchange Direct Program Costs (1,000 AED)

Lamp Type	Watts	Replacement Cost (AED)	Number of Lamps (1000)	Cost of CFL 50% Rebate Program	Cost of CFL 100% Rebate Program	Cost of Incandescent and Halogen Exchange Program
Incandescent	40	100.00	7,087	354,358	708,715	708,715
Incandescent	60	100.00	31,260	1,563,025	3,126,049	3,126,049
Incandescent	100	110.00	7,298	401,367	802,733	802,733
High-efficiency CFL	8	100.00	1,330	14,611	29,222	
High-efficiency CFL	14	100.00	12,647	138,977	277,953	
High-efficiency CFL	23	110.00	2,064	24,954	49,907	
Low-efficiency CFL	14	100.00	235	8,690	17,380	
Low-efficiency CFL	23	100.00	2,232	82,659	165,318	
Low-efficiency CFL	28	110.00	364	14,842	29,683	
Halogen	50	100.00	1,944	108,011	216,023	216,023
Total Direct Costs*			**66,461**	**2,711,493**	**5,422,985**	**4,853,520**

It should be noted that the rebate costs presented in Table 6 and Table 7 are based on 100% participation in the rebate program. In reality, participation is likely to be less than 100%, reducing the total cost (amount of rebates) of the program.

Exchange Programs

Similar to rebates, a short-term exchange program (also referred to as free swap-out programs) would lower the first cost to consumers. Households could bring in their incandescent and halogen lamps (working or not) and trade them in for new EELs. As shown in Table 4, the direct cost of a CFL exchange program would be in the range of 732.7 million AED. This is slightly less than the cost of a 100% rebate program because the exchange program excludes free riders.

Exchange programs accelerate the depletion of the existing stock of low-efficiency lamps because the lamps are removed from service with certainty. Rebate programs do not collect the low-efficiency lamps; hence, there is the higher probability that they will continue to be used until failure. As with a rebate program, an exchange program would provide an ideal infrastructure for education and information dissemination because it would provide opportunities for direct contact with the individuals making the purchase decision.

2.2.2 Implications of Tariff Differences across Emirate

The potential source of funding for financial incentives also needs to be considered. A UAE-wide program would likely be more efficient based on economies of scale and would address funding availability issues across Emirates. For example, anticipated subsidy reductions would be a source of funding for the financial incentives. However, as shown in the Economic Assessment report, subsidy reductions vary across Emirates due to differences in tariff rates.

As noted previously, electricity tariffs vary by Emirate, which in turn influences the need or feasibility of incentive programs. Table 2 shows that in Abu Dhabi, the majority of the benefits accrue to the government in terms of subsidy reduction. This means that households have less financial incentive to switch to EELs due to the relatively low tariff rate. However, this also implies that the government has a strong motivation to incentivize the transition to EELs because they will realize significant reduction in electricity subsidies.

In contrast, almost all of the benefits accrue to households in Dubai. In Dubai, tariff rates have been set to be revenue neutral, and as a result, there is virtually no subsidy reduction for the Emirate. This implies that in Emirates with higher tariff rates, there is less need to provide households with incentives or financial support for transitioning to EEL. In addition, additional government revenue from subsidy reduction is not available to finance potential incentive programs.

2.3 Education and Information

In addition to incentives, a key component of the market transformation process will be developing and implementing educational and informational programs to increase household awareness and ensure proper understanding of the benefits of the EEL. Educational programs are commonly used worldwide to enhance the effectiveness of existing and forthcoming standards. Educational programs will need to be customized to account for the characteristics of the target audience. In addition, programs will need to involve continuous/ongoing media (re-education) campaigns, particularly in light of the transient nature of a large share of the population in the UAE.

According to the Pacific Northwest National Laboratory's report, *Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market* (Pacific Northwest National Laboratory, 2006), for the transition to CFLs and LED to be lasting, it is important for policies to disseminate information emphasizing product quality. Giveaway and rebate promotions often obscure retail price and lead to surprises when customers return to make a repeat purchase. Promoting the product as desirable through means of education, attractive packaging, attribute marketing, and product demonstrations are effective ways of introducing new lighting products and influencing long-term behavior. All of this would increase acceptance of EELs and help with enforcement and persistence of the benefits of the standard.

Educational campaigns should be designed to address specific barriers to adoption relevant for households in the UAE. For example

- Price Concerns: The per-unit prices of CFLs and LEDs are noticeably higher than incandescents. Households need to be educated on both a) the potential electricity bill savings and b) the difference in life expectancy leading to no real change in annualized lamp expenditures.
- Performance Issues: Low-quality EELs will have shorter life expectancy and consume more electricity than high-quality products. Households need to be aware they will "get what they pay for" and that low-priced imitations are not less expensive in the long run.
- Aesthetics: EELs have a historical perception of having inferior light quality. Households need to be made aware of recent technology advances and that testing and monitoring will take place as part of implementing the standard to ensure product quality.
- Environmental and Health Concerns: Many households are aware that CFLs contain mercury. Individuals need to be informed that disposal guidelines have been developed and will be implemented in the near future. In addition, households need to be educated on what steps to take in the event of accidental breakage of CFLs in order to ensure safety and instill confidence.

In addition, it is important that awareness and educational campaigns be centralized and/or closely coordinated across Emirates to convey a consistent message. Consistency of messaging is critical to any successful education campaign. Conflicting information on the timing, requirements, and guidelines related to the standard will result in confusion and will diminish the effectiveness of the standard. Consistent information is essential through the supply chain—from suppliers to retailers to households. Having a centralized organization overseeing and coordinating informational and educational activities has proven to be the best approach to ensuring consistency.

2.3.1 Components of Lighting Awareness and Educational Activities

To effectively design and implement a successful consumer awareness and information program, a range of activities need to be undertaken. **Table 8** lists the typical program activities.

Table 8. Components of a Lighting Awareness and Information Program

Activities	Description
Lighting Energy Awareness Survey	Survey residential households to document awareness and activities related to EELs as baseline for future awareness programs. Document attitudes to different types of EEL and perceived issues of lighting quality, safety, and environmental issues.
Workshops and Supply Chain Outreach	Retailers, building managers and owners need to understand the benefits (energy cost savings) associated with complying with the regulations. They also need to be aware of the consequences (penalties) of violating the regulations.
Mass Media Education and Information Campaigns	Implement awareness and educational campaigns through a combination of media events at public shopping malls, other public gathering places, schools, and mass media outlets.
Evaluation of Campaign Effectiveness	Document how consumers respond to informational and educational campaigns regarding their lighting behavior and attitudes. Make adjustments to follow-up informational programs and assess persistence and needed frequency for ongoing activities.

Lighting Awareness Survey

DSM programs have often demonstrated that a key step in changing behaviors is increasing the awareness of available products, their costs, and their benefits. An awareness survey is the first step in the process because it assesses the situation and provides a starting point from which educational and informational materials can be developed. For example, some households may be aware of the existence of CFLs, but not realize they can safely operate in existing fixtures. Or other households may be aware that they are more expensive, but may not understand the cost impact of their longer life expectancy.

An awareness survey will provide information on these issues, as well as identify differences in knowledge and perceptions across demographic groups. Income, nationality, and geographic location may all impact awareness. For example, demographics will likely influence a household's ability to understand and respond to informational and education activities regarding their lamp purchases. Demographics may also influence a household's willingness to participate in different types of recycling programs. Knowledge of these factors will help inform the design and dissemination of informational materials and provide a baseline from which the impact of subsequent mass-media campaigns can be evaluated in the future.

Workshops and Supply Chain Outreach

Educational and informational programs will not only be needed for households and consumers of lamps, but also for a wide range of groups throughout the supply chain. Building managers, maintenance staff, and building owners, as well as retailers, need to understand the incentives (i.e., energy cost savings) associated with complying with the regulations. They also need to be aware of the consequences (penalties) of violating the regulations.

Retailers and building managers will need to understand the fundamentals of the regulation and the labeling system and have advanced notice of the timing of its roll out. Retailers and building managers will need to understand the procedures for any rebates or exchange programs, and procedures for returning leftover low-efficiency lamp stock to lamp suppliers (if applicable). Retailers will also need to be able to answer questions related to energy efficiency and the underlying motivation for the regulation. The supply chain needs to be an active advocate for the standard and promote awareness and education.

Mass Media Education and Information Campaigns

It will be important to develop and implement an education and information campaign for residential lighting end users to increase the awareness of the benefits (cost, health, environmental) of installing EEL villas and residential buildings. Through educational programs, this strategy will empower households to adopt EELs and identify simple changes in lifestyle that reduce lighting energy consumption. Programs with centralized distribution and processing would provide an opportunity for education and information dissemination. Education and information campaigns will include a wide range of activities:

- Distribution of newsletters and other print material through direct mailing and inserts into electric bills;
- Press releases for print, TV, and the Internet;
- Booths and media events at shopping malls and other public gathering places; and
- Interaction with the educational system providing materials, presentations, and workshops.

It will be important to build on existing activities, such as the Heroes of the UAE campaign (described below), RSB's Powerwise initiative, and DEWA's energy-efficiency campaign.

Heroes of the UAE is a national campaign encompassing a multi-tiered nationwide advertising and public relations program to inspire and help the public in its quest for energy and water efficiency. The Energy program developed a calculator to assess carbon emissions and has distributed thousands of EEL bulbs to the general public.

Evaluation of Campaign Effectiveness

Follow-up surveys should be conducted to assess the effectiveness of the educational and information campaigns. It is likely that modifications will need to be made to the materials, and that additional outreach activities will need to be developed as the campaign and public awareness evolve. In addition, as population demographics shift, purchasing patterns change and technology evolves, the education and information campaign will need to be updated to remain effective and relevant.

2.4 Environmental Protection and Sustainability

A lighting standard that moves towards the mandatory adoption of EEL needs to consider not only the direct benefits of reduced energy consumption and associated emissions, but also other potential impacts (and co-benefits) of EEL adoption. Sustainability seeks to balance the environmental, economic, and social impacts of technologies and policies to create a strategy and a standard that will provide the greatest benefit to all sectors while minimizing negative impacts.

From a sustainability perspective, a significant majority (90–95%) of energy consumption for all lighting products occurs in the use phase. Because fossil fuel is a major source of energy production, the majority of the environmental impacts also occur in the use phase. Incandescent light bulbs are the least energy-efficient and use approximately 4 times more energy than CFLs and LEDs. Currently, the UAE produces almost all of its electrical energy through natural gas power plants. Relative proportions of environmental impacts will change with changes to the sources of fuel in the electricity grid (e.g., movement to alternative and renewable energy).

As summarized in **Sections 1.3.2 and 1.3.3**, and detailed in the Sustainability Impact Assessment report, the energy savings and associated reductions in GHG emissions from electricity production make the implementation of high-efficiency lighting an attractive solution for the lighting sector. Subsidizing the transition to EEL may be a more efficient investment than subsidizing increased power production (from conventional or alternative sources) from a government perspective. At the consumer level, EEL appear to pay for themselves in almost all applications due to their extended life and reduced energy consumption as compared to incandescent bulbs.

CFLs are one near-term option for lamp upgrades. However, although CFLs consume less energy and have a longer lifetime than incandescent lamps, they do contain mercury. LEDs do not use mercury and thus do not have the same breakage and end-of-life management concerns as CFLs.

However, LEDs cost 5 to 7 times more at the point of purchase than CLFs. A key tradeoff between CFLs and LEDs is the mercury content of CFLs and the currently higher purchase price of LEDs.

One issue will be the financing of disposal, reuse, recycling and recovery programs across the Emirates. As shown in Table 2, not all Emirates will realize the same levels of subsidy reductions associated with reduced electricity reduction. Thus, individual Emirates will have different revenue sources available to fund such programs. In addition, the current and planned arrangements for Abu Dhabi to supply electricity to the Northern Emirates further complicate the financing of sustainability program. Whereas sorting and collection is, by necessity, a local activity, centralization of transportation, recycling, and recovery should be centralized wherever possible. Environmental and health risk assessments focused on potential mercury release from spent CFLs and LFLs would also help to better characterize potential concerns about their use and shape policy for safe handling and end-of-life management.

3. Regulatory Framework Process

This section outlines the structure typically used for the regulatory framework for lighting standards and provides discussion on key issues that need to be addressed and considered. This section is not intended to be a draft regulation, but should be considered as input into the development of the residential lighting standard. The section follows the general framework outlined in EU lighting regulations and directives such as the following:

- **EU COMMISSION REGULATION (EC) No 245/2009:** Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high-intensity discharge lamps, and for ballasts and luminaires able to operate such lamps.
- **DIRECTIVE 2010/30/EU** on the indication by labeling and standard product information of the consumption of energy and other resources by energy-related products.
- **EU DIRECTIVE 2002/96/EC** on waste electrical and electronic equipment (WEEE).

An overview of the EU framework is included in **Appendix A**.

3.1 Product Requirements for Lamps

The lighting standards cover a range of general requirements, including safety, energy efficiency, hazardous substance requirements, and safe disposal. The following is a summary of what is commonly included in these requirement categories

3.1.1 Electrical Safety

Electrical safety is the foremost concern and cornerstone of any technical lighting regulation. Most countries have technical regulations, such as the Emirates Conformity Assessment Scheme (ECAS) for Low Voltage Equipment (LVE). In addition, there are well-established applicable technical regulations that can be references, such as the components of the IEC standard for electrical safety.

3.1.2 Performance: Energy Efficiency

The efficiency of a lamp is typically defined relative to the power consumption of a comparable (same luminous flux) standard incandescent lamp. The ratio of the power consumption of the EEL and the reference power consumption provides the lamps' Energy Efficiency Index (EEI). Different classes of energy efficiency lamps can then be defined in terms of EEI ranges. Preliminary Energy Efficiency Classes (also referred to as Star Ratings) have been put forth in the draft *Regulation for Safety, Safe Disposal and Energy Efficiency of Lighting Products in UAE* and are shown in **Table 9**. Most incandescent lamps do not qualify for a 1 Star Rating, and most CFLs and LEDs currently fall in the 3–4 Star Ratings.

Table 9. Energy Efficiency Classes for Lamps

Energy-Efficiency Class	Energy-Efficiency Index (EEI) for Non-Directional Lamps
5 Star (Most efficient)	EEI ≤ 0.11
4 Star	0.11 < EEI ≤ 0.17
3 Star	0.17 < EEI ≤ 0.24
2 Star	0.24 < EEI ≤ 0.60
1 Star (Least efficient)	0.60 < EEI ≤ 0.80

Table 10 presents the EEI for the lamps modeled in the Economic Assessment and Sustainability Impact Assessment reports and indicates their Star Rating based on the proposed UAE Energy Efficiency Classes. These reports simulated the economic and environmental impact of phasing out three categories of lamps residential lamps, incandescents, halogens, and low-efficiency CFLs. This corresponds to an EEI of at least 0.24, which corresponds to a 3 Star Rating or better.

Table 10. EEIs and Star Ratings for the Lamps Used in the Analysis for This Study

Lamp Type	Watts	Lumens	Efficacy (Lumens per Watt)	P_{ref}*	EEI	Star Rating**
Incandescent	40	420	10.5	39	1.04	None
Incandescent	60	720	12.0	59	1.02	None
Incandescent	100	1380	13.8	100	1.00	None
High-efficiency CFL	8	416	52.0	38	0.21	3
High-efficiency CFL	14	770	55.0	62	0.23	3
High-efficiency CFL	23	1380	60.0	100	0.23	3
Low-efficiency CFL	14	516	36.9	45	0.31	2
Low-efficiency CFL	23	925	40.2	72	0.32	2
Low-efficiency CFL	28	1219	43.5	90	0.31	2
Linear florescent	18	1080	60.0	82	0.22	3
Halogen	20	286	14.3	29	0.69	1
Halogen	50	715	14.3	59	0.85	none
LED	6	312	52.0	31	0.19	4
LED	18	1008	56.0	77	0.23	3

* Based on the formulas provided above.

** Based on Table 9.

3.1.3 Functionality

Functionality requirements are important to ensure that product quality and international norms are well established. Functionality requirements cover parameters such as the following:

- Average life expectancy (lamp survival factor after a set number of operating hours)
- Lamp performance (lumen requirements after a set number of operating hours)
- Number of on-off switching cycles before failure
- Startup time (seconds)
- Lamp warm-up time (seconds)
- Premature failure rates (% failure within a fraction of life expectancy)
- Radiation levels (UVA, UVB and UVC levels)
- Lamp power factor (R_a)

- Color rendering

International best practices generally establish standardized testing procedures to ensure that lamps meet each of the functionality requirements listed above. In general, the testing standards specify the minimum number of samples that must be tested, the test apparatus and testing conditions, and the criteria for acceptability. For example, in the U.S., lamps must meet the following Energy Star criteria for color rendering:

- At least 10 sample lamps must be tested;
- Average color rendering index (CRI), as defined in CIE Publication No. 13.3 – 1995, of the 10 samples tested must be greater than 80, and no more than 3 individual samples can have a CRI less than 77; and
- Testing must be performed at a laboratory accredited by the National Voluntary Accreditation Program.

Some functionality testing requirements also specify the test duration (e.g., to certify average life expectancy) or the number of test cycles. A list of international standards commonly used for functionality testing is provided below:

- ANSI C78.376-2001: Specifications for the Chromaticity of Fluorescent Lamps
- ANSI C78.901– 2005: American National Standard for Electric Lamps – Single Base Fluorescent Lamps – Dimensional and Electrical Characteristics
- ANSI C78.5 – 1997: Specifications for Performance of Self-Ballasted Compacted Fluorescent Lamps
- ANSI/IEEE C62.41 – 1991 (01-May-1991): Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
- ANSI/IEC C81.61-2003: American National Standard for Electric Lamp Bases
- CIE Publication No. 13.3 – 1995: Method of Measuring and Specifying Color Rendering of Light Sources
- CIE Publication No. 18.2 – 1983: The Basis of Physical Photometry
- IESNA LM-9 – 1999: Electric & Photometric Measurement of Fluorescent Lamps
- IESNA LM-16: Practical Guide to Colorimetry of Light Sources
- IESNA LM-28-89 – 1989: Guide for the Selection, Care, and Use of Electrical Instruments in the Photometric Laboratory
- IESNA LM-40 – 2001: Approved Method for Life Performance Testing of Fluorescent Lamps
- IESNA LM-41-98 – 1998: Approved Method for Photometric Testing of Indoor Fluorescent Luminaires
- IESNA LM-54-99 – 1999: IESNA Guide to Lamp Seasoning
- IESNA LM-65-01– 2001: Approved Method for Life Testing of Single-ended Compact Fluorescent Lamps
- IESNA LM-66-00 – 2000: Electrical and Photometric Measurements of Single Ended Compact Fluorescent Lamps
- UL 1598 – 2004: UL Standard for Safety for Luminaires
- UL 1993 – 1993: Standard for Self-Ballasted Lamps and Lamp Adapters

3.1.4 Hazardous Chemicals

An important factor in limiting the impact of mercury from EELs on the environment and human health is to specify maximum mercury content for all products. Low quality CFLs typically have higher mercury content because decreasing the use of mercury in lamps increases manufacturing costs. As a result, low-quality products typically have significantly higher mercury levels. The low-efficiency CFLs discussed in the Baseline and Economic Assessment reports would likely be banned by the hazardous chemicals component of lighting standards.

Several options exist that allow countries to benefit from energy savings associated with EEL, such as CFLs and LFLs, while minimizing the potential amount of mercury released into the environment. For example, several countries place limits on the amount of mercury allowed in lamps, as summarized in **Table 11**. For the UAE, we recommend that mercury content limits be established to meet international best practice, such as the EU's Restriction of the Use of Certain Hazardous Substances (RoHS) in Electrical and Electronic Equipment Directive (2011/65/EU)[1], which specifies a limit of 2 mg mercury for 12W CFLs.

Table 11. Examples of Regulated Lamp Mercury Content Limits by Country

Country	Lamp Type	Mercury content Limit	Reference
Australia	CFLs	5 mg per lamp	AG, 2012
	LFLs	15 mg per lamp	
Canada	CFLs and LFLs	Reduce content by at least 80% from 1990 to 2010	Hilkene and Friesen, 2005
China	CFLs and LFLs	10 mg per lamp	UNEP, 2010
European Union member countries	CFLs	Currently: 5 mg per lamp By 2012: 3.5 per lamp By 2013: 2.5 mg per lamp	European Commission, 2010; UNEP, 2010
	LFLs	Currently: ▪ 10 mg in halophosphate lamps ▪ 5 mg in triphosphate lamps with a normal lifetime ▪ 8 mg in triphosphate lamps with a long lifetime By 2012: ▪ 3-4 mg in triphosphate lamps with a normal lifetime ▪ 5 mg in triphosphate lamps with a long lifetime	
California	CFLs	5 mg per lamp	CA DTSC, 2012
	LFLs	10 mg in halophosphate lamps 5 mg in triphosphate lamps with a normal lifetime 8 mg in triphosphate lamps with a long lifetime	

Several technologies exist which enable manufacturers to ensure that the amount of mercury in the lamps adhere to mercury limiting regulations while meeting the required lamp performance. Examples of technologies include injecting precise amounts of mercury using mercury amalgam, mercury alloy pellets, mercury alloy rings, or mercury capsule (UNEP, 2011). These technologies allow manufacturers to reduce the amount of mercury used and in some cases replace elemental mercury with less hazardous forms, while minimizing environmental and health hazard risks during manufacturing, transportation, installation, use, storage, recycling and disposal, especially if lamps break (UNEP, 2011).

[1] http://www.bis.gov.uk/nmo/enforcement/rohs-home

In addition to mercury, other hazardous chemicals for which limits should be considered include lead (Pb), cadmium (Cd), hexavalent chromium (Cr^{6+}), polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE). For example, the RoHs Directive (2011/65/EU) requires each EU member state to adopt and enforce its measures. The RoHS Directive aims to restrict the use and distribution of products that contain hazardous substances commonly used in electronic and electronic equipment. Specifically, the Directive bans the placing on the EU market of new electrical and electronic equipment containing more than the agreed levels of lead, cadmium, mercury, hexavalent chromium, PBB, and PBDE flame retardants. The directive promotes the use of safer alternatives to these substances and calls for aggressive recycling and re-use of electronic and electronic equipment waste.

RoHS places obligations on a number of different organizations, such as

- Manufacturers (inside and outside the EU), including those organizations having branded product made on their behalf.
- Authorized representatives acting on behalf of a manufacturer
- Importers of products into the EU
- Distributors of products within the EU, including organizations moving goods across national boundaries, distribution hubs and retailers supplying to end users

3.1.5 Marketing Requirements

Procedures for certification, labeling, and documentation will need to be established and revised as the MEPS become more stringent to block the entry of low-efficiency CFLs and other sub-par EELs.

Both dealers and suppliers will have responsibilities related to implementing labeling requirements. For example, dealers will need to display labels properly, in a visible and legible manner, and make the information available in the product brochure or other literature that accompanies products when sold to end-users. **Appendix A** contains additional details on package labeling frameworks and requirements for suppliers and dealers put forth by the EU.

Suppliers will be responsible for ensuring that information on packages and marketing materials is accurate and accessible to the full population. An issue for discussion is whether a customized UAE or a future Gulf Cooperation Council (GCC) country labeling system should be employed as part of the residential lighting standard, or if the use of existing EEL labeling requirements put forth by the international community would be sufficient. Additional customized labeling requirements will likely increase the effectiveness of the regulation. Labeling displayed in Arabic (as well as English) would be more accessible to a wider share of the population and would enhance public support by motivating national pride and ownership of the initiative. In addition, package labeling developed for the UAE could serve as template for a broader, GCC-wide labeling process in the future.

However, specialized labeling will increase the production and distribution cost of lamps to suppliers when doing business in the UAE, given the small size of the market. These additional costs will most likely be passed on to households in the form of increased lamp prices. For example, MELA estimates that the additional incremental cost from implementing a UAE label would range between U.S. dollar (USD) 0.25 (AED 0.92) and USD 0.75 (AED 2.75) per lamp. This represents a 7% to 21% increase in the price of a 14-watt, high-efficiency CFL (the most common EEL projected to be adopted). MELA also estimates that a GCC label would cause a lower price increase.

As shown in **Table 12**, the initial transition of replacing all incandescents, halogens, and low-efficient CFLs will require the purchase of 50 million lamps. The additional cost associated with a UAE label for the initial transition would range from 46 to 129 million AED. In the absence of government subsidies, these additional labeling costs would likely be borne by households.

Table 12. Potential Range of UAE Label Costs

	Number of Lamps (1,000)	Lower-Bound Cost per unit	Upper-Bound Cost per unit	Total Lower-Bound Cost	Total Upper-Bound Cost
Initial Transition Label Costs	50,420	AED0.92	AED2.75	46,387	138,655
Long-Run Annual Label Costs	8,434	AED0.92	AED2.75	7,759	23,193

The long-run estimate of increased labeling costs would translate into an UAE-wide increase of 7.8 to 23.2 million AED per year. The cost estimates are based on the current lighting stock of 85 million lamps, which, after the transition to EELs, will result in a life expectancy of just less than 10 years. Costs during the initial transition year(s) will be up to 7 times higher during the period when incandescent lamps are being replaced at a higher rate. As with the transition, the long-run labeling costs would be borne by households, but are relatively minor compared to the 459 million AED savings in annual electricity bills projected to accrue to households.

The payback analysis presented in Table 4 is recalculated for CFLs in **Table 13** to include the upper- and lower-bound UAE label costs. The payback from the government's perspective increases from 3.4 to 4.0 years. The social payback increases from 1.1 to 1.3 years.

Table 13. Payback with First Cost and UAE Label Costs (AED 1,000)

	First-Cost Replacement to CFLs No Label Cost (from Table 4)	First-Cost Replacement to CFLs Label Cost = AED 0.92 per Lamp	First-Cost Replacement to CFLs Label Cost = AED 2.75 per Lamp
Upgrade Cost	732,704	779,091	871,359
Subsidy Reduction (annual government benefits)	216,044	216,044	216,044
Government Payback (years)	3.4	3.6	4.0
Social Benefits (annual household + government)	667,911	667,911	667,911
Social Payback (Years)	1.1	1.2	1.3

3.2 Disposal, Reuse, Recycling, and Recovery

CFLs represent the most likely option for near-term bulb upgrades because they are relatively cost-effective and provide significant energy savings and related benefits. However, they contain mercury, which has raised concerns that they might lead to health and environmental impacts. Based on our analysis (RTI, 2012c), a ban on incandescent bulbs and wholesale upgrade to CFLs would translate to approximately 26 kilograms of mercury generated per year as part of spent bulb waste.

Aside from fluorescent lamps that contain mercury, lamps currently in use do not present significant disposal issues and are a very small fraction of total waste (and household hazardous waste) generated. As a result, recycling of mercury-containing lamps is non-existent in the UAE, with virtually all lighting products currently disposed in landfills in the UAE. However, compared to other countries where EELs standards have been implemented, few existing landfills in the UAE have modern environmental controls, such as double liners to prevent the leaching of toxic/hazardous materials (such as mercury) into the soil and groundwater. Although the mercury in a single CFL is relatively low, the large number of potential CFLs disposed translates into more significant amounts of mercury that have the potential to be released if proper end-of-life management schemes and infrastructure are not developed. The current state of waste management in the UAE for household-type wastes shows that minimal (but increasing) recycling is being conducted across the Emirates. There is a general lack of recycling institutions (both in the public and private sectors), which presents challenges for environmental protection and sustainability. In the EU and other countries, CFL recycling has been added to already existing services, significantly reducing the costs.

For the UAE to develop programs from scratch would be costly and time consuming; hence, the following options are put forth for consideration, along with their policy implications and institutional requirements

3.2.1 Waste Policy Options

For CFLs, policies will be needed that limit potential mercury release into the environment and are protective of worker health. The ESMA Sustainability Committee has developed a guidance document on the safe disposal of lighting products containing mercury in the UAE. As discussed in Appendix B, the guidance will closely follow the relevant technical guidelines from the Basel Convention with regards to safe disposal of mercury-containing lamps (see UNEP, 2011), as well as recommendations from the United Nation's Environment Programme (UNEP) document *Achieving the Global Transition to Energy Efficient Lighting Toolkit* (UNEP, 2012).

Relevant policies already exist such as Federal Law No. (24) of 1999, Cabinet order No. 37 of 2001, and these could be supplemented with additional policies, including the following:

- A land disposal ban that prohibits spent mercury-containing bulbs from being disposed in landfills. Such a ban would require institutional capacity for monitoring and enforcement and readily available options (recycling) for consumers.
- Extended Producer Responsibility (EPR) that requires lamp manufacturers to take responsibility for the post-consumer stage of lamp products. Typically, manufacturers are required to provide information on how and where recycling opportunities exist and may support such initiatives as the following:
  - *Retailer take-back.* Some retailers, such as home improvement, home furnishing, and other stores that sell lighting products may have programs that allow spent bulbs to be dropped off at the store.
  - *Reverse vending machines.* Vending machine-style recycling units, for example the reVend Light Bulb Recycling Reverse Vending machine in the United Kingdom,[2] are designed to accept domestic light bulbs. The machine automatically disposes of the bulb, and there is often a reward or monetary incentive (e.g., coupon or cash back) provided.
  - *Mail-back services*. Some bulb manufacturers and other organizations sell pre-labeled recycling kits that allow businesses and residents to mail used bulbs to recycling centers. The cost of each kit includes shipping charges to the recycling center. An individual can fill up a kit with old bulbs, seal it, and bring it to the post office or leave for his or her postal carrier.

  Due to the unique characteristics of lamps, compared to other types of household waste, collection and recycling costs are significant in relation to product prices. A unified legal EPR framework that moves towards the adoption of a single, industry-led collection and recycling service organization (CRSO), including a collective fund, would likely provide the lowest risk to individual companies and promote compliant behavior. Any such framework could be developed in cooperation with the UAE government, and the government would need to approve the framework and have oversight over its implementation.

[2] http://www.light-bulb-recycling.co.uk/index.html

- Municipal collection and recycling programs that are supported and subsidized by the governments of the UAE. These programs are typically organized and implemented by municipalities. Light bulbs may be collected at designated collection sites or may be picked up curbside, similar to other recycling programs. However, since municipal programs (and institutional capacity) are currently limited across the Emirates, it might take some time to establish a municipal program for mercury-containing bulb collection and management (e.g., safe disposal or recycling). Thus, it is recommended these programs be gradually phased in over time.

3.2.2 Recommendations: Short Term and Long Term

Short-Term Recommendations

- Establish EEL product standards with respect to mercury contents and the contents of any other hazardous substances. For CFLs, a limit of 2 milligrams of mercury per lamp has precedence in other countries and can be achieved without detracting from lamp performance. This will reduce the risk of residents and worker exposure to mercury in the case of CFL breakage.
- Develop or adopt guidance from international best practices for cleaning up broken mercury-containing lamps in the household, as well as for the safe collection, transport, storage, and disposal or recycling of spent mercury-containing lamps. For example, the UNEP's en.lighten toolkit contains guidance on the safe management of mercury-containing lamps.[3]
- Encourage the implementation of modern sanitary landfills with liner systems to prevent mercury and other toxic substances from entering the soil. This is consistent with the Basel Convention and overall environmental protection legislation as governed by UAE Federal Law No. 24.

Long-Term Recommendations

- Develop effective end-of-life management strategies for spent bulbs, particularly mercury-containing bulbs. The effects of a mandatory recycling law (or conversely, a landfill disposal ban) may have differing impacts on the various populations across the different Emirates. **Appendix B** contains a guidance document developed by a UAE sustainability subcommittee entitled *Guidance Document on the Safe Disposal of Lighting Products Containing Mercury in the UAE.*
- At this time, it is difficult to estimate what the costs may be per bulb recycled. Specific program designs would need to be defined, and detailed financial and environmental/health risk analyses conducted for the following:
    1. *Collection* of spent bulbs from household consumers by establishing take-back centers and reverse vending machines or through residential collection programs conducted by certified environmental service providers.
    2. *Recycling* (crushing) of bulbs at a designated centralized location with appropriate crushing and materials separation and containment machines. Markets for the reuse and recycling of collected materials would also need to be investigated.
    3. *Safe disposal* of hazardous waste in landfills with appropriately constructed (e.g., double liners) and operated facilities.
- EPR programs should also be examined that require manufacturers to take responsibility for the post-consumer stage of lamps, in particular mercury-containing lamps. Manufacturers could be required to provide information to consumers, through websites or other forms of outreach, on how and where recycling opportunities exist in the UAE. As mentioned in **Section 3.4.1**, an effective approach to EPR may be an industry-led and UAE government approved framework that moves towards a single CRSO.

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[3] http://www.enlighten-initiative.org/portal/CountrySupport/EfficientLightingToolkit/tabid/79082/Default.aspx

3.3 Product Certification Process

Products should be evaluated based on the requirements and standards set forth by the regulation. Certification should take into account product performance, direct health risks to users from routine use or breakage, and indirect environmental risks that could be mitigated by facilitating dismantling, recovery, and reuse of materials. To this end, producers should be required to certify the performance and safety of their projects. The product safety and certification process typically involves the following:

- Third-party product testing,
- Review and verification of results, and
- Certification and granting of certificate of conformity.For the residential lighting standard, this process could possibly involve leveraging a variety of testing resources, including in-country facilities and independent (i.e., out-sourced) third-party facilities and manufacturing facilities.

3.3.1 Third-Party Product Testing

Third-party product testing will be needed to verify performance and certify the Star Ratings specified in Table 10. The testing should be conducted at independent, certified testing laboratories. Over time, the UAE/ESMA will likely want to develop its own in-country testing facilities to certify EELs and perform ongoing testing and monitoring activities; however, in the near future, the combination of testing resources may need to be leveraged to meet the desired timeframe of the regulation. Whereas independent testing and monitoring are essential for the success of implementing the standard, they should not be viewed as a roadblock to achieving near-term energy savings from EELs.

Most international suppliers of lamps have substantial testing facilities and capabilities. These resources could be leveraged, at least in the short run. Smaller manufacturers or imports from countries with less-credible testing and labeling practices should be the initial focus of in-country testing.

The advantages of leveraging manufacturers' testing resources include the following:

- They can support quick ramp up to implement the regulation with their existing facilities, staff, and international experience, which could potentially help lower the overall cost of quality assurance to the UAE in the short run.

The disadvantages of leveraging manufacturers' testing resources include the following:

- Perceived conflict of interest by manufacturers;
- In general, increased supplier costs associated with testing could potentially be passed on to the consumers, increasing the price of EELs in the UAE; and
- Manufacturers throughout the world have different levels of testing capabilities and quality.

3.3.2 Review and Verification of Results

Independent verification will be needed to review manufacturing testing results. The growth of UAE testing capabilities would represent highly skilled employment opportunities for Nationals and could represent a service that could be expanded to other Gulf countries. Alternatively, the verification testing could be initially contracted to an independent third party, with the intent of capacity building over time.

In general, suppliers will need to produce technical documentation that is sufficient to enable the accuracy of the information contained in the label. That technical documentation will include the following:

- A general description of the product;

- Where relevant, the results of design calculations carried out;
- Test reports, where available, including those carried out by relevant certified organizations as defined under other legislation;
- Where values are used for similar models, the references allowing identification of those models.

3.3.3 Certification and Granting of Certificate of Conformity

- Following the Emirates Conformity Assessment Scheme, manufacturers, traders, and suppliers will be evaluated based on requirements set forth by the standards, and upon approval, will be granted a Certificate of Conformity. Manufacturers, traders, and suppliers will need to provide the following test reports as part of the certification process:
  - IEC CB Certificate and Referenced Test Report
  - Competent Third-Party Performance Test Report
  - Competent Third-Party Hazardous Chemical Composition Test Report.

3.4 Surveillance and Market Monitoring

Ongoing surveillance and market monitoring will be essential for achieving a lasting and fair market transition to EELs. ESMA, in coordination with different local government authorities, should be responsible for market monitoring of products to ensure compliance to this regulation.

At point of entry, inspections will be conducted, and products without the proper registration certificate will be impounded and not permitted entry. In addition, continuous random sampling of products at retail outlets will be needed. In the early stages of the regulation, market monitoring activities should focus on lighting products traded in Free Zones that have passed customs and are intended for UAE use.

3.5 Compliance, Verification, and Enforcement

A centralized UAE institution will need to lead the efforts for compliance, verification, and enforcement. UAE government inspectors can provide the highest level of assurance that codes and standards are being followed. In addition, a centralized UAE institution, such as ESMA, could help monitor the flow of products in the initial months of the regulation to ensure that an adequate supply of lamps is reaching the public, and address any market barriers that are identified.

Inspector training will be an important component for achieving the savings potential of the standard because the primary enforcement mechanism will likely be import control at the border. The ban on incandescents (which represents over 90% of savings) should be relatively straightforward to implement because of the obvious visual differences in the lamps. However, restricting entry of low-quality EELs may be more complicated and require knowledge of the technologies, as well as the labeling and certification process. In addition, there are almost always exemptions for selected types of incandescents and halogen lamps, such as applications for household appliances, automotive lighting, and display optic lamps.

Several key issues related to import control and re-export are highlighted below:

- **Managing Free Zones.** An important aspect of managing and enforcing the regulation will be working with the multiple Free Zones throughout the UAE. To be effective, the regulation will need to cover lighting products traded in Free Zones that have passed customs and are intended for UAE use. There are likely to be differences in operation across the Emirates, as well as differences in control and enforcement practices and capability across Emirates. A committee should be established to investigate operating practices and assess how best to roll out the standard across the UAE.

- **Inspecting Retail Outlets and Managed Properties.** The UAE will need to develop a monitoring system where government inspectors conduct market surveillance (inspections/auditing) to ensure compliance at the retail outlets. As part of this, inspectors will need to have the capability/authority to do the following:
  - Conduct random inspections of shops and managed buildings to ensure compliance with the standard.
  - Enforce penalties, as needed, for not complying with the regulations.
- **Distance Selling.** Products are offered for sale/purchase by mail order, by catalogue, or through the Internet or telemarketing will also be covered by the standard. However, enforcing the ban may be more problematic due to the number of entry points into the country.

4. Timing of Energy Savings and Environmental Impacts

It is anticipated that all components of the regulation discussed in Section 3 will be implemented simultaneously; that is, all EEI and environmental requirements will be put in place (not phased in), which will effectively ban most incandescents, halogens, and low-efficiency CFLs as they either will not meet the minimum EEI or the hazardous chemical requirements. However, to ease market transformation, the role out of the standard will likely include a grace period for manufacturers importing into the UAE, as well as a grace period for retailers to deplete existing inventories. Without these grace periods, implementation of the standard would likely be infeasible or prohibitively expensive in the short run.

As a result, there are several factors that will determine the timing of energy savings and the corresponding economic and environmental impacts. These include the date when the standard is published, the length of the import and retail grace periods, and the time it takes for households to turnover their existing stock of lamps in use.

Because of uncertainty of the exact date the regulation will be published, we assume the publication of the regulation occurs at time (t) = 0. The following additional parameters are then used to define the timing of the realized energy savings:

- All regulations enter into force after the import and retail grace period; thus, banned products are not available to households at t = 6 months.
- The average product life expectancy is provided in **Table 14** and is to be used to estimate failure rates for banned products currently in use in households:
  - 12 months for incandescence lamps
  - 24 months for low-efficiency halogens
  - 36 months for low-efficiency CFLs.

As described in the Economic Assessment report, the failure rate within a technology would be evenly distributed over time, leading to a gradual ramp up in savings as the existing lamps in use fail and are replaced by EELs.

Table 14. Life Expectancy and Replacement Rate by Lamp Type

Lamp Technology	Life Expectancy (Hours)	Life Expectancy* (Years for full turnover of existing household lamps)
Incandescent	1,000	0.9
Halogen	2,000	1.8
Low-efficiency CFL	3,000	2.7
High-efficiency CFL	10,000	9.1
LEDs	50,000	45.7

* Assuming an average of 3 hours per day of use.

4.1 Timing of Energy Savings

Figure 8 illustrates the timeline for realized energy savings. The figure shows that energy savings phase-in over the time period of t = 13 to 48 months after the publication of the regulation. As described in the Baseline Assessment report, an estimated 35% of existing lamps in the UAE are currently incandescent and represent approximately 90% of potential savings. Thus, the majority of the savings are realized during the 13–24 month period that corresponds to the replacement of incandescent lamps.

Note that related policy activities conducted in parallel could accelerate the transition to EELs. Education and information campaigns could motivate households to switch out their incandescent and halogen lamps early (prior to failure). Exchange programs could also incentivize households to swap out their low-efficiency lamps prior to failure. Both of these policies have the potential to accelerate household adoption and shift the energy savings curve shown in Figure 8 to the left.

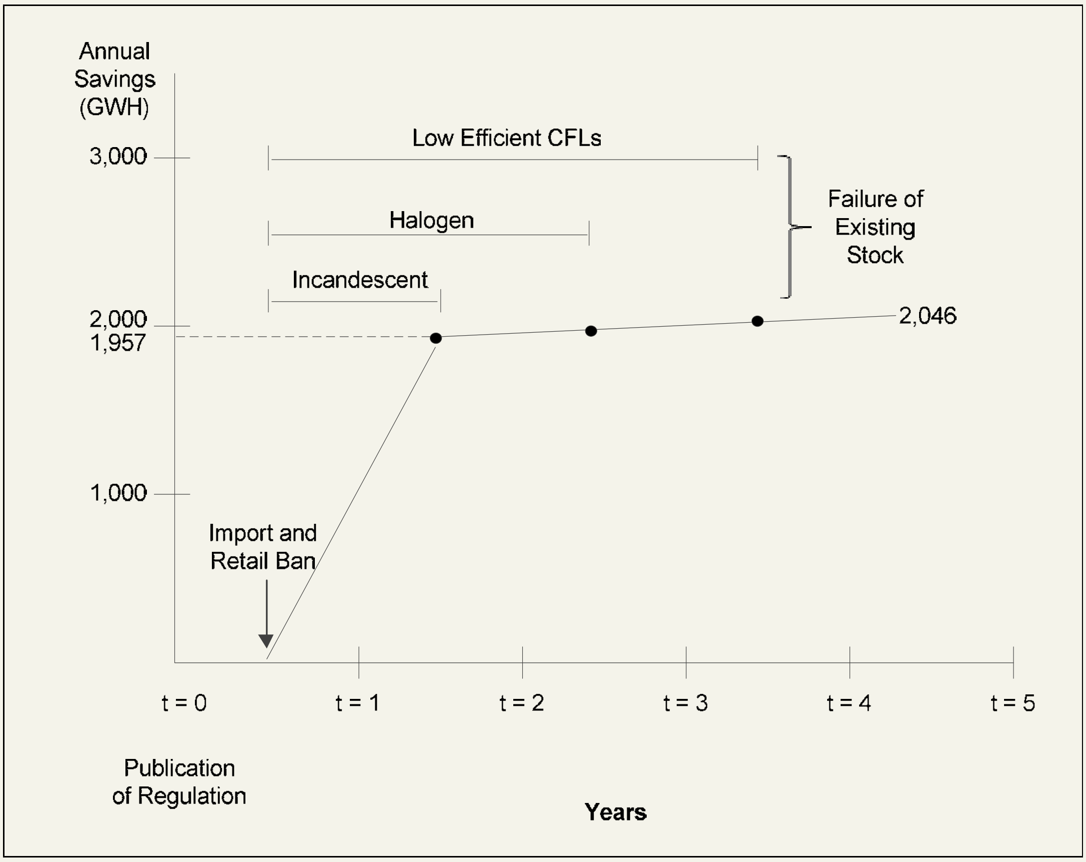

Figure 8. Timing of Energy Savings

4.2 Timing of Environmental Impacts

Reductions in emissions associated with power generation (CO_2, NO_x, SO_x, and PM) will directly parallel the timing of energy savings. However, the timing of additional mercury entering the waste management system as a result of the regulation is more complicated and will have lag.

The replacement of incandescent and halogen lamps with CFLs will eventually lead to increased mercury in the waste management system. However, with CFLs having an average life expectancy of about 9 years, the bulk of these new units will not fail until approximately 10 years after the publication of the regulation (including the 1/2-year grace period).[4] This could allow time for the UAE to mobilize a sustainable waste management system capable of processing the spent CFL lamps.[5]

In addition, the replacement of low-efficiency CFLs with high-efficiency CFLs should lead to a short-run decrease in mercury waste generated. As shown in the Sustainability Impact Assessment report, the combination of lower mercury content and longer life expectancy in high-efficiency CFLs leads to a reduction in waste mercury, and these benefits would be begin to be realized 4 years after the publication of the regulation.

Similarly, if LEDs are to be recycled due to their electronic components, significant numbers of LEDs should not be entering the waste disposal system for an extended period of time due to their average life expectancy of 45 years.

The implication of the timing of the environmental impacts is that, even though there are significant challenges to implementing sustainable recycling and recovery programs in the UAE, the lag in the generation of new toxic waste as a result of the regulation provides the timeframe to design and implement such programs if resources are mobilized quickly.

5. Conclusion

Phase-out of incandescent lamps, halogens, and low-efficiency CFLs would reduce direct lighting energy consumption by up to 65%. When including the cooling bonus, the potential savings from EELs in the residential sector is 2,046 GWh per year. Phasing out incandescents accounts for 92% of the savings potential. The elimination of halogen lamps accounts for 7% of savings and the elimination of low-efficiency CFLs from the market accounts for the remaining 1% of savings. Whereas there would be exceptions within all lamp technologies banned, the associated energy saving would be negligible.

All of the EEL substitution options being considered were found to economically viable in that the reduction in electric bills to households more than offset the incremental cost of the EELs. Total social benefits are estimated to be approximately 668 million AED per year after full adoption of EELs. The household sector benefits are estimated to be 459 million AED per year, and the subsidy reduction to government is 216 million AED per year after full adoption of EELs. If incremental UAE label costs are included, long-run household benefits decrease by approximately 2–5%, but all substitution options are still profitable for households.

Import restrictions are likely to be the most effective means of implementing the regulation. With an import ban, the majority of the savings could be achieved with minimal new institutional burden. The ban on incandescent lamps would be relatively straightforward because of the obvious visual differences in the lamps. A ban on halogens should also be straightforward to implement; however, their impact is relatively small.

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[4] Actual failure rates will have a probability distribution around the average. Usage rates will vary, and some lamps will fail earlier and some later.

[5] It is important to note that CFLs currently represent a 35% market share of residential lamps, and hence, a sustainable waste management system should be implemented as soon as possible to process existing lamps.

Phasing out low-quality CFLs, while important, will be more costly from an institutional and implementation perspective and will yield limited energy savings. This will require a more sophisticated testing and monitoring system and a higher level of training for inspectors (relative to a ban on incandescents). Thus, it is recommended that phasing out low-quality EELs should be pursued, but should not delay the ban on incandescent lamps. However, lower-quality EELs have a greater impact on the environment due to shorter life expectancy and higher levels of toxic metals. Thus, in the long run, it is imperative that these inefficient EELs be eliminated from the UAE.

The environmental and sustainability issues are important for achieving national goals and enhanced international reputation and for gaining public support and managing public opinion. Plans outlined in the *Guidance Document on the Safe Disposal of Lighting Products Containing Mercury in the UAE* (see **Appendix B**) for addressing the disposal issues should be implemented in parallel with the publication and implementation of the regulation. Whereas there are significant challenges to implementing sustainable recycling and recovery programs in the UAE, the lag in the generation of new toxic waste as a result of the regulation provides the timeframe to design and implement such programs if resources are mobilized quickly.

Finally, it is recommended that a 1- to 2-year incentive program accompany the roll out of the residential lighting standard. Either a lamp rebate or an exchange program would help households with the financial transition to EELs. The upper-bound cost of a rebate or exchange program would be approximately equal to the annual social benefits (assuming 100% participation, which is unlikely). Financial incentives could then be discontinued after the first 2 years. The economic analysis does not support the need for prolonged incentive programs.

In addition, incentive programs with centralized distribution and processing would provide an opportunity for education and information dissemination, all of which would increase acceptance of EELs and help with enforcement and persistence of the benefits of the standard.

5.1 Roles and Responsibilities: UAE versus Individual Emirates

Early in the process of developing the regulation, implementing organizations and their roles and responsibilities will need to be identified. While it is beyond the scope of this study to propose specific organizations for specific roles, **Table 15** distinguishes between activities that may best be conducted at a national UAE level versus roles that may be better suited to be performed at the individual Emirate level.

Table 15. Roles and Responsibilities

UAE National-level Leadership	Combination with Centralized Leadership	Individual Emirates Leadership
Product safety testing and certification processes	Managing EPR activities of manufactures and suppliers	Collection and separation programs
Product quality testing and certification process	Transportation to centralized recycling facility	Disposal and modifications to existing waste collection processes and landfill design/construction
Package labeling requirements	Managing centralized recycling facility	
Enforcement and penalties	Education and information programs	
Revising requirements for lamps and ballasts on a periodic basis	Funding and implementation of incentive programs	

For example, import/export control is regulated at the UAE level, being primarily a function of the UAE Council. From this perspective, testing, inspection, and enforcement of the import bans would be a federal activity, as well as any updates or modifications to the standards or labeling that would be maintained by ESMA.

It is less clear at what level it is best to implement education and information programs—although all activities should be coordinated by a centralized organization. National UAE-wide programs could provide economies of scale in the development of materials and delivery mechanisms. Centralized programs would also ensure that a consistent message is being communicated, which is important to gain acceptance. Ongoing programs, such as Heroes of the UAE, could be leveraged. In addition, several Emirates also have ongoing energy-efficiency campaigns through their urban planning councils or environmental agencies, which could generate synergies and collaborative opportunities.

The implementation of separation and lamp collection is an area where individual Emirates may need to take the lead roles, and their strategies may vary. Waste collection and disposal is a local activity, and different Emirates have different systems in place, different resources available, and different social goals. Whereas UAE-wide objectives, recommendations, and/or regulations could be put forth, operationally, it would likely fall to the individual Emirates to implement the collection and sorting, and/or upgrades to landfills.

Due to economies of scale, it will likely be most efficient for the UAE to develop a centralized recycling, reuse, and final disposal facility to handle CFL and LED lamps. This could be part of a larger facility dedicated to recycling and the processing of hazardous waste in general. Issued of transporting hazardous waste across Emirate borders will need to be addressed. Current UAE laws have specifications that restrict the transport of waste across Emirate borders. However, a centralized transportation infrastructure may be most effective in licensing and monitoring the trucking fleet.

Whereas significant subsidy reduction is a potential source of funding for implementation, rebates/exchange programs, and education activities associated with the EEL standard, subsidy benefits from reduced electricity generation vary greatly across the Emirates. Thus, centralization of many aspects of the regulation may be desirable, not only for an efficiency perspective, but also from a financing perspective. Smaller Emirates may not have the resources or realize the subsidy reductions needed to implement and enforce the regulation. Inconsistent monitoring and enforcement will dampen the standard's effectiveness.

5.2 Additional Information Needs and Follow-Up Analysis

It is recommended that the UAE move forward with the residential lighting standard as soon as possible. Even though there are several areas of uncertainty where better data would improve the quantitative analysis, the net benefits to households and the government are undisputedly positive and significant.

One area where limited information is available is related to low-quality CFLs and LFLs. The pervasiveness of low-quality CFLs currently in use in the UAE impacts energy savings, economic, and environmental impact estimates presented these studies. It is recommended that additional information be collected from testing results on the characteristics and prevalence of low-quality CFLs and LFLs (i.e., energy consumption, life expectancy, and levels of heavy metals) to document their elimination.

In addition, it is recommended that a system be put in place to track the market penetration and public perception of EELs to document the impact of any incentive programs and verify realized energy savings.

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Appendix A

EU Regulatory Frameworks

The following outlines the lighting regulation framework based on EU regulations. Section A.1 provides more details that may be considered for inclusion.

Article 1 Subject matter and scope

- Lamp and ballast standards
- Product safety
- Package labeling
- Disposal

Article 2 Definitions

Article 3 Exemptions

Article 4 Requirements for lamps and ballasts

4.1 Lamp efficacy requirements
4.2 Lamp performance requirements
4.3 Lamp labeling
4.4 Ballast energy performance requirements
4.5 Ballast labeling

Article 5 Product Safety Certification Process

5.1 Application submission
5.2 Third-party product testing
5.3 Review and verification of results
5.4 Certification and granting of certificate of conformity
5.5 Surveillance and Market Monitoring

Article 6 Package labeling requirements

6.1 Responsibilities of suppliers
6.2 Responsibilities of dealer
6.3 Distance selling and other forms of selling
6.4 Free movement
6.5 Public procurement and incentives

Article 7 Disposal, reuse, recycling, and recovery

7.1 Product design
7.2 Separate collection
7.3 Treatment
7.4 Recovery
7.5 Cost
7.6 Information for users
7.7 Information for treatment facilities
7.8 Information and reporting
7.9 Adaptation to scientific and technical progress

Article 8 Enforcement

8.1 Ensure Compliance
8.2 Non-compliance
8.3 Report of enforcement activities

Article 9 Penalties

Article 10 Transposition

Specifies the date that the laws, regulations and administrative provisions will be brought into force.

Article 11 Repeal

Article 12 Revision

Article 13 Entry into force

A.1 Additional Detail on the EU Framework

The EU has multiple regulations (references 1-3) that when combined into chapters, could form a comprehensive lighting standard. The first reference provides an outline for the specifications of the lighting standard, including labeling of lamps. The second reference provides an outline for information to be included on packaging and inserts. The third reference outlines regulations for disposal of lamps. The three regulations below have been rearranged to combine Articles and their corresponding Annexes. Articles were renumbered as necessary.

The EU is requiring increased lamp efficiency over time, resulting in staged regulations (i.e. First, Second, and Third Stage), which were removed from this outline for simplicity.

1. **EU COMMISSION REGULATION (EC) No 245/2009:** implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council as amended by Commission Regulation (EU) No 347/2010

Article 1 Subject matter and scope

Article 2 Definitions

- ‘general lighting’
- ‘discharge lamp’
- ‘ballast’
- ‘luminaire’
- ‘fluorescent lamps’
- ‘fluorescent lamps without integrated ballast’
- ‘high intensity discharge lamps’
- ‘Directional Light Source’ (DLS)
- ‘White light source’
- A ‘rated’ value
- A ‘nominal’ value
- ‘Light pollution’
- ‘Obtrusive light’
- ‘Efficiency Base ballast’ (EBb)
- ‘Second lamp envelope’
- ‘Light source control gear’
- ‘High-pressure mercury (vapour) lamp’
- ‘High-pressure sodium (vapour) lamp’
- ‘Metal halide lamp’
- ‘Electronic or high frequency ballast’
- ‘Clear lamp’

Article 3 Technical parameters

3.1 Technical parameters for ecodesign requirements

(a) 'Luminous efficacy of a source', 'light source efficacy' or 'lamp efficacy' (ηsource),
(b) 'Lamp Lumen Maintenance Factor' (LLMF),
(c) 'Lamp Survival Factor' (LSF),
(d) 'Ballast efficiency' (ηballast),
(e) 'Chromaticity',
(f) 'Luminous flux',
(g) 'Correlated Colour Temperature' (Tc [K]),
(h) 'Colour rendering' (Ra),
(i) 'Specific effective radiant UV power',
(j) 'Ingress protection grading'

3.2 Technical parameters for indicative benchmarks

(a) 'Lamp mercury content',
(b) 'Luminaire Maintenance Factor' (LMF),
(c) 'Utilisation Factor' (UF)

Article 4 Exemptions

Article 5 Requirements for fluorescent and high intensity discharge lamps and ballasts and luminaires able to operate such lamps

5.1 Lamp efficacy requirements

- Table 1: Rated minimum efficacy values for T8 and T5 lamps
- 'Table 2: Rated minimum efficacy values for single capped fluorescent lamps working on electromagnetic and electronic ballast
- 'Table 3: Rated minimum efficacy values for single capped fluorescent lamps, working only on electronic ballast
- Table 4: Rated minimum efficacy values for single capped fluorescent lamps with square shape or (very) high output
- Table 5: Rated minimum efficacy values for T9 and T5 Circular lamps
- 'Table 6: Deduction percentages for rated minimum efficacy values for fluorescent lamps with high colour temperature and/or high colour rendering and/or second lamp envelope and/or long life
- 'Table 7: Rated minimum efficacy values for high pressure sodium lamps with Ra ≤ 60
- Table 9: Rated minimum efficacy values for other high intensity discharge lamps
- Table 10: Rated minimum efficacy values for metal halide lamps

5.2 Lamp performance requirements

- '*Table 11:* Lamp lumen maintenance factors for single and double capped fluorescent lamps
- *Table 11a:* Deduction percentages for fluorescent lamp lumen maintenance requirements
- '*Table 12:* Lamp survival factors for single and double capped fluorescent lamps
- '*Table 13:* Lamp lumen maintenance factors and lamp survival factors for high pressure sodium lamps
- Table 14: Lamp lumen maintenance factors and lamp survival factors for metal halide lamps

5.3 Product information requirements on lamps

(a) Nominal and rated lamp wattage

(b) Nominal and rated lamp luminous flux
(c) Rated lamp efficacy
(d) Rated lamp Lumen Maintenance Factor
(e) Rated lamp Survival Factor
(f) lamp mercury content as X.X mg
(g) Color Rendering Index (Ra) of the lamp
(h) Color temperature of the lamp
(i) Ambient temperature at which the lamp was designed to maximize its luminous flux

5.4 Ballast energy performance requirements

- Table 16: Minimum efficiency for ballasts for high intensity discharge lamps

5.6 Product information requirements on ballasts

- 'Table 17 & 18: Energy efficiency index requirements for non-dimmable ballasts for fluorescent lamps
- Table 19: Energy efficiency index requirements for dimmable ballasts for fluorescent lamps

5.7 Luminaire energy performance requirements

5.8 Product information requirements on luminaires

Article 6 Product Safety Certification Process (based on Lighting regulation 1.pptx: \\rtifile02\sbs\Projects\0600033-EWS_Lighting\Technical\Stakeholders\Lighting regulation 1.pptx)

6.1 Application submission

6.2 Third-party product testing

6.3 Review and verification of results

6.4 Certification and granting of certificate of conformity

6.5 Surveillance and Market Monitoring

Article 7 Repeal

Article 8 Revision

Article 9 Entry into force

2. **DIRECTIVE 2010/30/EU** on the indication by labeling and standard product information of the consumption of energy and other resources by energy-related products

Article 1 Scope

1. This Directive establishes a framework for the harmonization of national measures on end-user information, particularly by means of labeling and standard product information, on the consumption of energy and where relevant of other essential resources during use, and supplementary information concerning energy-related products, thereby allowing end-users to choose more efficient products.

2. This Directive shall apply to energy-related products which have a significant direct or indirect impact on the consumption of energy and, where relevant, on other essential resources during use.

3. This Directive shall not apply to:

(a) second-hand products;
(b) any means of transport for persons or goods;

(c) the rating plate or its equivalent affixed for safety purposes to products.

Article 2 Definitions

(a) 'energy-related product' or 'product'
(b) 'fiche'
(c) 'other essential resources'
(d) 'supplementary information'
(e) 'direct impact'
(f) 'indirect impact'
(g) 'dealer'
(h) 'supplier'
(i) 'placing on the market'
(j) 'putting into service'
(k) 'unauthorised use of the label'

Article 3 Enforcement

1. Ensure Compliance
2. Non-compliance
3. Report of enforcement activities

Article 4 Information requirements

(a) information relating to the consumption of electric energy, other forms of energy and where relevant other essential resources during use, and supplementary information is brought to the attention of end-users by means of a fiche and a label related to products offered for sale or displayed to end-users directly or indirectly by any means of distance selling, including the Internet;
(b) the information referred to in point (a) is provided in respect of built-in or installed products only where required by the applicable delegated act;
(c) any advertisement for a specific model of energy-related products covered by a delegated act under this Directive includes, where energy-related or price information is disclosed, a reference to the energy efficiency class of the product;
(d) any technical promotional material concerning energy- related products which describes the specific technical parameters of a product, namely, technical manuals and manufacturers' brochures, whether printed or online, is provided to end-users with the necessary information regarding energy consumption or shall include a reference to the energy efficiency class of the product.

Article 5 Responsibilities of suppliers

(a) suppliers placing on the market or putting into service products covered by a delegated act supply a label and a fiche in accordance with this Directive and the delegated act;
(b) suppliers produce technical documentation which is sufficient to enable the accuracy of the information contained in the label and the fiche to be assessed. That technical documentation shall include:
    (i) a general description of the product;
    (ii) where relevant, the results of design calculations carried out;
    (iii) test reports, where available, including those carried out by relevant notified organizations as defined under other Union legislation;
    (iv) where values are used for similar models, the references allowing identification of those models.

(c) suppliers make the technical documentation available for inspection purposes for a period ending five years after the last product concerned was manufactured.
(d) in respect of labeling and product information, suppliers provide the necessary labels free of charge to dealers. Without prejudice to the suppliers' choice of system for delivery of labels, suppliers promptly deliver labels on request from dealers;
(e) in addition to the labels, suppliers provide a product fiche;
(f) suppliers include a product fiche in all product brochures. Where product brochures are not provided by the supplier, the supplier provides fiches with other literature provided with the product;
(g) suppliers are responsible for the accuracy of the labels and fiches that they supply;
(h) suppliers are considered to have given consent to the publication of the information provided on the label or in the fiche.

Article 6 Responsibilities of dealers

(a) dealers display labels properly, in a visible and legible manner, and make the fiche available in the product brochure or other literature that accompanies products when sold to end-users;
(b) whenever a product covered by a delegated act is displayed, dealers attach an appropriate label, in the clearly visible position specified in the applicable delegated act, and in the relevant language version.

Article 7 Distance selling and other forms of selling

(a) Where products are offered for sale, purchase by mail order, by catalogue, through the Internet, telemarketing or by any other means which imply that the potential end-user cannot be expected to see the product displayed, delegated acts shall make provision to ensure that potential end-users are provided with the information specified on the label for the product and in the fiche before buying the product.
(b) Delegated acts shall, where appropriate, specify the way in which the label or the fiche or the information specified on the label or in the fiche shall be displayed or provided to the potential end-user.

Article 8 Free movement

1. Member States shall not prohibit, restrict or impede the placing on the market or putting into service, within their territories, of products which are covered by and comply with this Directive and the applicable delegated act.

2. Unless they have evidence to the contrary, Member States shall consider labels and fiches as complying with the provisions of this Directive and the delegated acts. Member States shall require suppliers to provide evidence within the meaning of Article 5 concerning the accuracy of the information supplied on their labels or fiches when they have reason to suspect that such information is incorrect.

Article 9 Public procurement and incentives

1. Where a product is covered by a delegated act, contracting authorities which conclude public works, supply or service contracts shall endeavor to procure only such products which comply with the criteria of having the highest performance levels and belonging to the highest energy efficiency class. Member States may also require the contracting authorities to procure only products fulfilling those criteria. Member States may make the application of those criteria subject to cost-effectiveness, economical feasibility and technical suitability and sufficient competition.

2. Paragraph 1 shall apply to contracts having a value equal to or greater than the established thresholds.

3. Where Member States provide any incentives for a product covered by a delegated act they shall aim at the highest performance levels including the highest class of energy efficiency laid down in the applicable delegated act. Taxation and fiscal measures do not constitute incentives for the purpose of this Directive.

4. Where Member States provide incentives for products, both for end-users using highly efficient products and for industries which promote and produce such products, they shall express the performance levels in terms of classes as defined in the applicable delegated act, except where they impose higher performance levels than the threshold for the highest energy efficiency class in the delegated act. Member States may impose higher performance levels than the threshold for the highest energy efficiency class in the delegated act.

Article 10 Delegated acts

1. The Commission shall lay down details relating to the label and the fiche by means of delegated acts in accordance with Articles 11 to 13, relating to each type of product in accordance with this Article.
2. The criteria referred to in paragraph 1 are the following:
   (a) according to most recently available figures and considering the quantities placed on the Union market, the products shall have a significant potential for saving energy and, where relevant, other essential resources;
   (b) products with equivalent functionality available on the market shall have a wide disparity in the relevant performance levels;
   (c) the Commission shall take into account relevant Union legislation and self-regulation, such as voluntary agreements, which are expected to achieve the policy objectives more quickly or at lesser expense than mandatory requirements.
3. In preparing a draft delegated act, the Commission shall:
   (a) take into account environmental parameters which are relevant for the end-user during use;
   (b) assess the impact of the act on the environment, end-users and manufacturers, including small and medium-sized enterprises (SMEs), in terms of competitiveness including on markets outside the Union, innovation, market access and costs and benefits;
   (c) carry out appropriate consultation with stakeholders;
   (d) set implementing date(s), any staged or transitional measures or periods, taking into account in particular possible impacts on SMEs or on specific product groups manufactured primarily by SMEs.
4. The delegated acts shall specify in particular:
   (a) the exact definition of the type of products to be included;
   (b) the measurement standards and methods to be used
   (c) the details of the technical documentation (i.e. label and fiche);
   (d) the design and content of the label, which as far as possible shall have uniform design characteristics across product groups and shall in all cases be clearly visible and legible. The format of the label shall retain as a basis the classification using letters from A to G; the steps of the classification shall correspond to significant energy and cost savings from the end-user perspective; and use a consistent color scale.

   The classification shall be reviewed in particular when a significant proportion of products on the internal market achieves the two highest energy efficiency classes and when additional savings may be achieved by further differentiating products.

(e) Detailed criteria for a possible reclassification of products are, where appropriate, to be determined on a case-by-case basis in the relevant delegated act;

(f) the location where the label shall be fixed to the product displayed and the manner in which the label and/or information are to be provided in the case of offers for sale as covered by Article 7.

(g) the content and, where appropriate, the format and other details concerning the fiche or further information specified in Article 4 and Article 5(c). The information on the label shall also be included on the fiche;

(h) the specific content of the label for advertising, including, as appropriate, the energy class and other relevant performance level(s) of the given product in a legible and visible form;

(i) the duration of label classification(s), where appropriate, in accordance with point (d);

(j) the level of accuracy in the declarations on the label and fiches;

(k) the date for the evaluation and possible revision of the delegated act, taking into account the speed of technological progress.

Article 11 Exercise of the delegation

1. Ability to adopt delegation
2. Report on the delegation
3. The powers to adopt delegated acts are conferred on the Commission subject to the conditions laid down in Articles 12 and 13.

Article 12 Revocation of the delegation

1. States who is capable of revoking the delegation of powers referred to in Article 10.
2. Report the reasons for revocation within a reasonable time before the final decision is taken.
3. The decision of revocation shall put an end to the delegation of the powers specified in that decision. It shall take effect immediately or at a later date specified therein. It shall not affect the validity of the delegated acts already in force.

Article 13 Objections to delegated acts

1. Time period for rejection
2. If, on expiry of that period, no objections have been made, it shall be published and enter into force on the date stated therein.

Article 14 Evaluation

The aim and effectiveness of the directive is reviewed and considered for amending.

Article 15 Penalties

Rules shall be established on penalties applicable to infringements of the national provisions adopted pursuant to this Directive and its delegated acts, including unauthorized use of the label, and shall take the necessary measures to ensure that they are implemented. The penalties provided for shall be effective, proportionate and dissuasive.

Article 16 Transposition

Specifies the date that the laws, regulations and administrative provisions necessary to comply with the Directive will be brought into force.

Article 17 Repeal

Previous regulations will be repealed upon the date stated in Article 16.

Article 18 Entry into force

This Directive shall enter into force on the day following its publication

3. EU DIRECTIVE 2002/96/EC on waste electrical and electronic equipment (WEEE)

Article 1 Objectives

The purpose of this Directive is, as a first priority, the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, e.g. producers, distributors and consumers and in particular those operators directly involved in the treatment of waste electrical and electronic equipment.

Article 2 Scope

Includes the following Lighting Equipment:

a. Luminaires for fluorescent lamps with the exception of luminaires in households
b. Straight fluorescent lamps
c. Compact fluorescent lamps
d. High intensity discharge lamps, including pressure sodium lamps and metal halide lamps
e. Low pressure sodium lamps
f. Other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs

Article 3 Definitions

(a) 'electrical and electronic equipment' or 'EEE'
(b) 'waste electrical and electronic equipment' or 'WEEE'
(c) 'prevention'
(d) 'reuse'
(e) 'recycling'
(f) 'recovery'
(g) 'disposal'
(h) 'treatment'
(i) 'producer'
(j) 'distributor'
(k) 'WEEE from private households'
(l) 'dangerous substance or preparation'
(m) 'finance agreement'

Article 4 Product design

The design and production of electrical and electronic equipment shall be encouraged to take into account and facilitate dismantling and recovery, in particular the reuse and recycling of WEEE, their components and materials. In this context, Member States shall take appropriate measures so that producers do not prevent, through specific design features or manufacturing processes, WEEE from being reused, unless such specific design features or manufacturing processes present overriding advantages, for example, with regard to the protection of the environment and/or safety requirements.

Article 5 Separate collection

1. Member States shall adopt appropriate measures in order to minimize the disposal of WEEE as unsorted municipal waste and to achieve a high level of separate collection of WEEE.

2. The collection and transport of separately collected WEEE shall be carried out in a way which optimizes reuse and recycling of those components.

3. Establishes a standard for the minimum separate collection in average kg per inhabitant per year of WEEE from private households.

Article 6 Treatment

1. Member States shall ensure that producers or third parties acting on their behalf, in accordance with Community legislation, set up systems to provide for the treatment of WEEE using best available treatment, recovery and recycling techniques. The systems may be set up by producers individually and/or collectively. The treatment shall, as a minimum, include
   (a) the removal of all fluids and
   (b) Selective treatment for materials and components of waste electrical equipment
      — removal of mercury containing components, such as switches or backlighting lamps,
      — removal of gas discharge lamps,
      — gas discharge lamps: The mercury shall be removed.
   (c) Taking into account environmental considerations and the desirability of reuse and recycling, collection and separation shall be applied in such a way that environmentally-sound reuse and recycling of components is not hindered.
   (d) For the purposes of environmental protection, Member States may set up minimum quality standards for the treatment of collected WEEE.
2. Member States shall ensure that any establishment or undertaking carrying out treatment operations obtains a permit from the competent authorities. The inspection shall verify:
   (a) the type and quantities of waste to be treated;
   (b) the general technical requirements to be complied with;
   (c) the safety precautions to be taken.
3. Any treatment operations shall comply with the following technical requirements
   (a) Sites for storage (including temporary storage) of WEEE prior to their treatment
   (b) Sites for treatment of WEEE

Article 7 Recovery

1. Member States shall ensure that producers or third parties acting on their behalf set up systems either on an individual or on a collective basis, to provide for the recovery of WEEE collected separately.
2. Sets targets by a specified date.
3. Member States shall ensure that, for the purpose of calculating these targets, producers or third parties acting on their behalf keep records on the mass of WEEE, their components, materials or substances when entering (input) and leaving (output) the treatment facility and/or when entering (input) the recovery or recycling facility.
4. Member States shall encourage the development of new recovery, recycling and treatment technologies.

Article 8 Financing in respect of WEEE from private households

1. Producers provide at least for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE from private households deposited at collection facilities.

2. Each producer shall be responsible for financing the operations referred to in paragraph 1 relating to the waste from his own products. The producer can choose to fulfill this obligation either individually or by joining a collective scheme.

Article 9 Information for users

1. Member States shall ensure that users of electrical equipment in private households are given the necessary information about:
   (a) the requirement not to dispose of WEEE as unsorted municipal waste and to collect such WEEE separately;
   (b) the return and collection systems available to them;
   (c) their role in contributing to reuse, recycling and other forms of recovery of WEEE;
   (d) the potential effects on the environment and human health as a result of the presence of hazardous substances in electrical equipment;
   (e) the meaning of the symbol for the marking of electrical equipment, indicating separate collection for electrical equipment.
2. Member States shall adopt appropriate measures so that consumers participate in the collection of WEEE and to encourage them to facilitate the process of reuse, treatment and recovery.
3. With a view to minimizing the disposal of WEEE as unsorted municipal waste and to facilitating its separate collection, Member States shall ensure that producers appropriately mark electrical and equipment with the symbol, indicating separate collection for electrical equipment. In exceptional cases, where this is necessary because of the size or the function of the product, the symbol shall be printed on the packaging, on the instructions for use and on the warranty of the electrical and electronic equipment.
4. Member States may require that some or all of the information referred to in paragraphs 1 to 3 shall be provided by producers and/or distributors, e.g. in the instructions for use or at the point of sale.

Article 10 Information for treatment facilities

1. In order to facilitate the reuse and the correct and environmentally sound treatment of WEEE, including maintenance, upgrade, refurbishment and recycling, Member States shall take the necessary measures to ensure that producers provide reuse and treatment information for each type of new EEE put on the market within one year after the equipment is put on the market.
2. A mark on the electrical equipment will specify the date it was placed on the market in order to promote the use of these standards.

Article 11 Information and reporting

1. Member States shall draw up a register of producers and collect information, including substantiated estimates, on an annual basis on the quantities and categories of electrical and electronic equipment put on their market, collected through all routes, reused, recycled and recovered within the Member States, and on collected waste exported, by weight or, if this is not possible, by numbers.
2. Reports shall be drawn up at specified intervals.

Article 12 Adaptation to scientific and technical progress

1. Amendments should be considered to possibly add luminaires in households and filament bulbs.
2. Before the Annexes are amended the Commission shall *inter alia* consult producers of electrical and electronic equipment, recyclers, treatment operators and environmental organizations and employees' and consumer associations.

Article 13 Penalties

Member States shall determine penalties applicable to breaches of the national provisions adopted pursuant to this Directive. The penalties thus provided for shall be effective, proportionate and dissuasive.

Article 14 Inspection and monitoring

Member States shall ensure that inspection and monitoring enable the proper implementation of this Directive to be verified.

Article 15 Transposition

Article 16 Entry into force

Appendix B

Guidance Document for the Safe Disposal of Lighting Products Containing Mercury in the UAE (Working Document, November 2012)

Introduction

The purpose of the document is to be used as a guidance on how wastes from lighting products, should be managed within the UAE. In particular, some energy efficient lighting (EEL) products such as CFL's contain mercury (Hg) which is globally recognized as a hazardous pollutant (Basel Convention, 2010). Given that the Emirates Standardization and Metrology Authority (ESMA) is approving a standards lighting regulation that will increase the use of EEL in the UAE, it is particularly important to indicate how spent lamps containing mercury should be safely disposed of.

This document builds upon the "Road Map for Safe Disposal Article in Lighting Regulations" that was discussed by the Sustainability Committee set up by Esma. It mainly highlights the relevant technical guidelines from the BASEL Convention with regards to safe disposal of mercury containing lamps from the *Basel Convention, Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of Elemental Mercury and Wastes Containing or Contaminated with Mercury* (Basel Convention, 2010) , as well as recommendations from the UNEP document *Achieving the Global Transition to Energy Efficient Lighting Toolkit* (UNEP, 2012).

General considerations on safe disposal of lighting products:

- Certain types of Energy Efficient Lighting (EEL) contain mercury, such as CFLs which require safe management and disposal
- To fully benefit from the transition to energy efficient lamps, to avoid future environmental and health risks, countries should establish collection and recycling systems for CFLs and other mercury-added lamps (UNEP, 2012).Law 24 provides general information on waste management, but is not specific enough for hazardous waste; the development of the UAE lighting regulation should take the latter into account, as well as the waste management plans currently been developed and implemented by the Ministry of Environment and Water, and other Emirates
- Mercury regarding EEL should be managed with a dual strategy:
  - Reducing Hg levels per light bulb through the lighting regulation following international best practices, and specifically the RoHs Directive. These limits on mercury content have been included in the UAE lighting regulation.
  - Maximizing the safe disposal (including proper handling, collection, storage, transportation, treatment, recycling or disposal) of mercury-containing light bulbs so the least amount goes into general waste.
- Extended producer responsibility (EPR) could be used as an instrument to encourage the production of mercury-free or less mercury containing products and collection of end-of-life products (BASEL Convention, 2011).
- Environmental authorities should develop regulatory frameworks setting out the responsibilities of relevant stakeholders, management of products, and components of EPR programmes, if any, and encourage participation by relevant parties and the public. In the UAE, the Ministry of the Environment and Water (MoEW) should set these regulatory frameworks, in coordination with the appropriate Emirate level authorities, for the safe disposal of electronic waste and wastes consisting of elemental mercury and wastes containing. or contaminated with mercury. This document can support the development of such regulatory frameworks relative to the safe disposal of mercury containing light bulbs.

- If an EPR program were to be established in the UAE, the responsibility should be placed on all producers of the products considered, and free riders (producers who do not share their responsibilities) should not be allowed, otherwise other producers are forced to bear costs that are disproportionate to their product market share (Basel Convention, 2011).Whenever appropriate for the UAE, the regulation could include off-the-shelf best practice international regulations.

  Outline of safe disposal of lighting products in the UAE:

1. Legal Status of waste from lighting products

    - Legal status of waste from lighting products will indicate how spent light bulbs should be collected, and treated.

  1.1. Waste categories of spent light bulbs

    - The following categories of lighting technologies should be treated as general waste following Law 24:
      - Incandescent light bulbs;
      - Halogens.
    - The following categories of lighting technologies should be treated as Hazardous wastes, following the Basel Convention and the guidance provided in this document:
      - Mercury containing light bulbs (CFL's and LF's)
      - Electronic waste light bulbs (LED's)
    - As new lighting technologies emerge, these categories should be reviewed by the environmental authorities.

  1.2. Labeling of waste

    - A labelling system should be implemented by the producer in the packaging to help consumers and collection/recycling programmes learn which products that contain mercury and need special handling (Basel Convention, 2011).
    - A labeling system in the packaging should specify that it is a "mercury-added product" and could achieve the following objectives as described in Section F in the BASEL Convention technical guidelines for the environmentally sound management of wastes (Basel Convention, 2011):
    - Informing consumers at the point of purchase that the product contains mercury and may require special handling at the end-of-life;
    - Identifying the products at the end of disposal so that they can be kept out of the waste stream destined for landfill or incineration and thus be recycled;
    - Informing consumers that a product contains mercury, so they have information on safer alternatives (such as LEDs in the case of CFL's);
    - Providing right to know disclosure for a toxic substance.
    - International standards have been developed for the proper labelling and identification of wastes (UNEP, 2012). The following reference materials are useful for labelling waste in the UAE:
      - UNECE (2003): Globally Harmonized System of Classification and Labeling of Chemicals.
      - OECD (2001b): Harmonized Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures.

2. Collection of mercury containing light Bulbs

2.1. General considerations

- Mercury containing light bulbs should be collected intact to avoid breakage (UNEP, 2012).
- Mercury containing lamps are to be discarded in a specially designed container at a waste collection station or drop off depot to avoid mixing waste containing mercury with other waste (UNEP, 2012). Additional details will be provided in section 2.1.b.
- Consumers should be able to take spent light bulbs to collection stations free of charge.

2.2. Collection stations[6]

- Collection at the communal and neighborhood level:
  - The challenges that need to be anticipated of collection at the communal/neighborhood level are the health risk of repeat exposure to individuals in case of breakage, misunderstanding from consumers on separation requirements, collection schedules and logistics (UNEP, 2012).
  - To ensure efficient collection of waste containing mercury by local collectors, an initiative or legal mechanism will be required. For example, governments, producers of mercury-added products or other agencies will need to provide arrangements for the collection of waste containing mercury by local collectors on a regular basis (UNEP, 2012). The committee discussed that a dedicated pick up service from collection points could provide an effective solution.
- Collection at the communal and or Retail level:
  - Advantages of collection at the communal and or retail level-Accessible. Retailers are interested and affected parties and perceived to have responsibility with regard to mercury containing light bulbs. This collection scheme could be integrated with selected items from other mercury containing wastes (UNEP, 2012).

2.3. Collection site design

- Containers for waste collection should consider the following guidelines:
- CFLS and other mercury containing light bulbs should be collected intact to avoid breakage (UNEP, 2012).
- Spent light bulbs containing mercury should be discarded in a specially designed container at a waste collection station to avoid mixing mercury containing waste with other waste (UNEP, 2012).
- Boxes or containers for mercury containing lamps should be made available at waste collection stations (Basel Convention, 2011).
- Only containers specifically designed and shown to be capable of containing mercury vapour from broken lamps should be used in public collection locations (UNEP, 2012).
- Breakage of CFLs should be avoided through appropriate box design and by providing written information on collection procedures. Collection containers should minimize the "free fall" of the lamp by installing soft, cascading baffles or flaps. Another more desirable option to minimize breakage is that the consumer hands the CFLs to competent and trained staff of a collection station who place the lamps in a box (UNEP, 2012).

[6] The Sustainability Committee discussed the possibility of establishing collection at the household level. The committee concluded that this alternative was not practical and was costly, mainly because the waste generated from spent light bulbs would not justify setting such a collection program.

- Designated containers should all be the same color and/or bear the same logo to facilitate public education and increased participation (UNEP, 2012).
- Monitoring of waste collection site:
  - The boxes or containers should be labeled and placed where they can be monitored in a well-ventilated area, for example, outside the building in a covered and secure space (UNEP, 2012). The temperature of waste collection site should be maintained as low as feasibly possible, preferably at a constant temperature of 21°C.
  - Authorised collectors, such as municipal collectors or private sector collectors (e.g. collectors authorized by the appropriate authorities), should gather the waste in the waste collection containers. They should pay particular attention to the prevention of evaporation and spillage of elemental mercury into the environment. Such waste should be placed in a gas- and liquid-tight container that bears a distinctive mark indicating that it contains "toxic" elemental mercury (Basel Convention, 2011).

2.4. Broken lamps procedure

- Analyses of various CFLs health risks conclude that with adequate ventilation and proper clean up, a broken CFL is very unlikely to lead to mercury exposure that creates any significant threat. The most effective strategy to prevent health risks is to provide accurate factual information describing the potential risks, and also to provide clear, useful advice about how to prevent and address breakages (UNEP, 2012).
- Critical variables that influence the risk from a broken CFL or mercury containing light bulb include: the amount of mercury the bulb contains; the chemical and physical form(s) of that mercury; the fraction of mercury that escapes on breakage; the absorbency of the surface onto which mercury is released; how long mercury remains in or around the breakage site; environmental factors such as temperature, room volume, rate and timing of ventilation; and, most importantly, clean-up actions taken by the consumer. A broken CFL can release mercury vapour, which is of most concern within enclosed spaces without ventilation (UNEP, 2012).
- Education and information to consumers regarding safe disposal is described in section 10 of this document.
- Broken lamps procedure should be provided at the collection point.

2.5. Roles and responsibilities

- Consumers would be responsible for transporting spent light bulbs to initial collection point. They should receive adequate information, such as specified in section 9, to avoid lamp breakage.
- Lamp collection systems should be designed and operated by qualified and government appointed third parties.
  - This could either be the responsibility of the relevant government authority or third party authority working on their behalf which could be BEE'AH Sharjah for all emirates
  - This could also be the EPR who would assume the financial and operational burden of collection of the products they are putting on the market. For an EPR system to be effective it is indispensable that there is a level playing field for all producers putting products in the UAE market.
- Retailers could be responsible for promoting the collection of light bulbs by putting in place a combined visible disposal fee and take back collection program, where consumers would receive a refund on part of the visible disposal fee for returning their spent light bulb (details on Article 9).

- Guidelines for special containers could be developed by the Ministry of Environment and water.

3. In-Country Transportation of wastes of mercury containing light bulbs

- For transporting wastes containing or contaminated with mercury from public collection points to waste treatment facilities should be properly packaged and labeled (Basel, 2011).
- Proper packaging and labeling regulations should be developed by the MOEW as part of the federal waste strategy. The following reference materials are helpful to develop such regulations (Basel, 2011):
  - UNECE (2003): Globally Harmonized System of Classification and labelling of chemicals;
  - OECD (2001): Harmonized Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures;
  - As well as document from IATA, IMO and UNCE.
- For transporting CFLs and other mercury containing lamps from generators' premises or public collection points to waste treatment facilities, the waste should be properly packaged and labeled (UNEP, 2012).
- Vehicle requirements are necessary for proper transportation; hazardous wastes need to be transported in closed and unexposed vehicles.
- The transport has to be authorized by the corresponding municipal authorities, both sending and receiving the waste. A federal regulation for transport is being currently developed by the MOEW to facilitate waste transport between the Emirates.
- Companies transporting wastes within the country should be certified as carriers of hazardous materials and wastes by XXXXX, and their personnel should be qualified (Basel Convention, 2011).
  - Employees of transporting hazardous waste have to be appropriately trained.
- For transport and transboundary movement of hazardous wastes, the following documents should be consulted to determine specific requirements (BASEL Convention, 2011) and should be taken into account when developing the UAE legislation regarding hazardous wastes or dangerous goods transportation legislation:
  - Basel Convention: Manual for the Implementation of the Basel Convention (SBC 1995a);
  - International Maritime Organization (IMO): International Maritime Dangerous Goods Code (IMO 2002);
  - International Civil Aviation Organization (ICAO): Technical Instructions for the Transport of Dangerous Goods by Air (ICAO 2001);
  - International Air Transport Association (IATA): Dangerous Goods Regulations Manual (IATA 2007);
  - UNECE: United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations (UNECE 2007).
- During transportation, hazardous waste should be identified, packaged and transported in accordance with the United Nations Recommendations on the Transport of Dangerous Goods: Model Regulations (Orange Book) (Basel, 2011).
- Persons transporting such waste should be qualified and certified as carriers of hazardous materials and wastes (Basel, 2011; UNEP, 2012).

- Guidance on the safe transportation of hazardous materials can be obtained from the International Air Transport Association, International Maritime Organization, and United Nations Economic Commission for Europe and the International Civil Aviation Organization (Basel, 2011).

3.1. Roles and responsibilities

- The MOEW should develop appropriate regulations for the packaging, labeling and transport of hazardous waste, including waste form mercury containing light bulbs; as well as set up the appropriate coordinating mechanisms between Emirates taking into consideration international best practice guidelines and regulations as specified above.
- Transport of mercury containing waste light bulbs could be part of the EPR, or assumed by a third party contractor authorized by the MOEW. In any case, transportation of waste from mercury containing light bulbs should adhere to UAE legislation and the Basel Convention, and its corresponding guidelines.

4. Temporary Storage

4.1. Storage guidelines

- Storage guidelines should follow the BASEL Convention technical guidelines and the Enlighten toolkit as indicated below:
- Waste containing mercury should be stored safely and kept apart from other waste until it is brought to waste collection facility or picked up by collection programmes or contractors.
- Waste should be stored by generators for a limited time, as allowed by federal standards, and sent off-site for appropriate disposal as soon as is practical.
- Household waste containing CFLs or mercury containing light bulbs should be stored temporarily after appropriately packaging the light bulbs.
- Any mercury containing light bulbs that are broken in the course of handling should be cleaned-up and all clean-up materials stored outdoors until collection for further management.
- It is important to properly store wastes consisting of elemental mercury and waste containing or contaminated with mercury after collection but before disposal. The technical requirements for storage of hazardous waste should be complied with, including national standards and national and international regulations. The risk of contamination to other materials should be avoided.

4.2. Storage site design

- Storage site design should follow the BASEL Convention technical guidelines (Basel, 2011) below;
- Storage facilities should not be built in sensitive locations such as floodplains, wetlands, groundwater, earthquake zones, Karst terrain, unstable terrain or areas with unfavourable weather conditions and incompatible land use, in order to avoid any significant risks of mercury release and possible exposure to humans and the environment.
- The mercury waste storage area should be designed to ensure that there is no unnecessary chemical or physical reaction to mercury. The floors of storage facilities should be covered with mercury-resistant materials. Additionally, these facilities should not be used to store other liquid waste and materials.
- Storage facilities should have fire alarm systems and fire suppression systems and have negative pressure environments to avoid mercury emissions to the outside of the building.

- The temperature in storage areas should be maintained as low as feasibly possible, preferably at a constant temperature of 21°C.
- The storage area for wastes consisting of elemental mercury and wastes containing or contaminated with mercury should be clearly marked with warning signs.
- A full inventory of the waste kept in the storage site should be created and updated as waste is added or disposed of.
- Regular inspection of storage areas should be undertaken, focusing particularly on damage, spills and deterioration.
- Clean-up and decontamination should be carried out speedily, but not without alerting the authorities concerned.
- Access to waste containing mercury, such as waste form mercury containing lamps, should be restricted to those with adequate training for the purpose including in recognition, mercury specific hazards and handling.
- The temperature of waste collection site should be maintained as low as feasibly possible, preferably at a constant temperature of 21°C.
- In terms of safety for facilities, site-specific procedures should be developed to implement the safety requirements identified for storage of waste consisting of elemental mercury and wastes containing or contaminated with mercury. A workable emergency plan, preferably with multiple procedures, should be in place and implemented immediately in case of accidental spillage and other emergencies.

4.3. Roles and responsibilities

- The MOEW should develop appropriate regulations for the storage of hazardous waste, including waste from mercury containing light bulbs; as well as set up the appropriate coordinating mechanisms between Emirates. These regulations should take into consideration international best practice guidelines as specified above.

5. Treatment and recovery/recycling of mercury containing light bulbs

5.1. Treatment guidelines

- Treatment should follow the Basel guidelines, which specify environmentally appropriate pre-treatment and treatment requirements for recycling and reclamation of Hg compounds
- Recycling facilities should not be restricted to one specific technology or solution but allow for a number of different appropriate technologies. The Basel guidelines contain detailed description of the technologies for *Recycling/reclamation of mercury and mercury compounds* in section G related to *Environmentally Sound Disposal*.
- Through utilization of lamp processing equipment, the main objective of these systems is to prevent loss of mercury vapour and mercury-containing phosphor powder to the environment while recovering materials for primary recycling (UNEP, 2012).
- Mercury-added lamp waste management systems generally involve the following steps: crushing or shredding the lamps into small pieces; separating the crushed or shredded materials into different components for subsequent processing; mercury-recovery; and waste treatment and disposal processes for materials that remain, either before or after mercury recovery (UNEP, 2012).
- Pre-treatment- Before undergoing thermal treatment, wastes containing mercury or contaminated with mercury are treated to increase the efficiency of the thermal treatment; the pre-treatment processes include removal of materials other than those containing

mercury by crushing and air separation, dewatering of sludge and removal of impurities (UNEP,2012).

- Lamp glass from crushed mercury-added lamps can retain mercury, and for some end uses, should be treated thermally, or in other ways to remove mercury, before sending it for reuse or disposal. If the glass is re-melted, the melting unit should have air pollution controls specifically designed to capture released mercury (such as activated carbon injection) (UNEP, 2012).

5.2. Treatment and recovery/recycling site design

- Treatment site design should follow the BASEL Convention technical guidelines below (Basel, 2011):
  - To minimize mercury emissions from the mercury recovery process, a facility should employ a closed system.
  - The entire process should take place under reduced pressure to prevent leakage of mercury vapour into the processing area.
  - Various methods for recycling of gas-discharge lamps are described in detail in the Basel Guidelines. They include the following: the shredder method, used for all types of discharge lamps, including energy-efficient lamps; the end cut method, for linear fluorescent lamps; the crush and sieve method, used for all types of fluorescent lamps: the centrifugal separation method, used for CFLs; and the high intensity discharge lamp processor, used for high-mercury content lamps to help improve recovery and reduce cross-contamination of equipment. Product-specific stripping methods yield maximum recycling rates.
  - The *Technical Guidelines on the Environmentally Sound Recycling/Reclamation of Metals and metal Compounds (R4)* of the Basel Convention address the environmentally sound recycling and reclamation of metals and metal compounds including mercury (UNEP, 2012). It is possible to recycle waste consisting of elemental mercury and waste containing or contaminated with mercury, in special facilities which have advanced mercury-specific recycling technology. It should be noted that appropriate procedures should be employed in such recycling to prevent any releases of mercury into the environment (UNEP, 2012).

5.3. Materials that are to be recycled apart from mercury

- The elements found in mercury containing light bulbs are glass, ferrous and non-ferrous materials, phosphor powder (rare earths), flame retardant chemicals, and plastics (UNEP, 2012).
- The Phosphors help produce high lamp efficiency and color rendering (UNEP, 2012). Phosphor powder is becoming a more valuable commodity as the value for rare earth phosphors increases. Limited available resources, trade issues and increasing costs are entering into greater demand for recycled rare earth phosphors.
- LED lamps also contain electronic waste and other components that need to be separated from general waste and could be recycled.
- Most of the materials have little or no value and therefore the recycler must recover processing costs from the generators (UNEP, 2012).

5.4. Sale of recyclable materials

- In the case that recyclable materials are sellable, these need to comply with BASEL guidelines Section G titled *Environmentally sound disposal* (Basel, 2011)

5.5. Roles and responsibilities

- This could either be the responsibility of the relevant government authority or third party authority working on their behalf which could be BEE'AH Sharjah for all emirates
- This could be included in the EPR who would assume the responsibility of the treatment, recycling and disposal of the products.

6. Permanent Disposal for non-recyclable materials or waste from mercury containing light bulbs

6.1. Materials to be disposed

- Waste management regulations at the Federal and Emirate level should incorporate the permanent disposal of materials that are not recyclable.
- For disposal of mercury waste, including mercury containing light bulbs, please refer to Section G titled *Environmentally sound disposal* (Basel, 2011)

6.2. Materials for export

- Any hazardous materials for export should follow BASEL Convention technical guidelines section F *Handling, separation, collection, packaging, labelling, transportation and storage* (Basel, 2011).

6.3. Roles and responsibilities

7. Landfill requirements

7.1. Mandatory sanitary requirements for landfills in the UAE

- Even though recycling of mercury containing light bulbs should be maximized, a rate of 100% recycling is hardly achieved. Therefore in order to minimize the negative impact of mercury containing light bulbs that might end as general waste, as well as other hazardous wastes, the landfill requirements in the UAE should be upgraded.
- Refer to section G and H in the BASEL Convention technical guidelines on environmentally sound disposal for specific guidance on this topic (Basel, 2011).

7.2. Roles and responsibilities

- It is recommended that the MOEW, in coordination with the relevant Emirate level authorities, include the appropriate landfill requirements in the development of the regulations and waste management systems currently been developed.

8. Financing of disposal of mercury containing light bulbs

8.1. Financing of collection program

- Financing through a visible advance disposal fee system combined with a deposit-refund take back collection program
  - A number of regulatory initiatives that stipulate the collection and recycling of all mercury-added lamps in line with extended producer responsibility norms, require producers to set up the system that will facilitate the collection and recycling for the lighting products. Major lamp manufacturers and national regulators have

successfully established take-back infrastructures for mercury-added lamps in some countries (UNEP, 2012).

8.2. Financing of storage facility

8.3. Financing of treatment and recovery/recycling centre

- Similar to above article 9.1

8.4. Financing of information and awareness tools and activities

- Producers may take on responsibility of awareness in the UAE along with the government, however specific measurable targets would need to be defined along with a monitoring plan.

9. Information for users regarding the safe disposal of mercury containing light bulbs

- Programmes for public awareness and public participation should generally be developed around a waste management situation at national/local/community level. Refer to Table 7 in the Basel Technical Guidelines section L on *Awareness and Participation* for details for programs on public awareness and education (Basel, 2011).
- In order to raise the awareness of citizens, the authorities concerned, e.g. local governments, need to initiate various awareness-raising and sensitization campaigns to enable citizens to take an interest in protection against the adverse effects to human health and the environment (Basel, 2011).
- Communication campaigns should always accentuate the positive and focus on the range of benefits and outcomes that end users will enjoy as a result of seeking out and selecting efficient lighting products. If end users can feel good about the outcome, they are more motivated to take an interest in seeking out information and to understand why it is meaningful to their purchasing decision. Dry, factual messages will have less impact than positive, beneficial statements (UNEP, 2012).
- When initiating activities such as the collection and recycling of waste containing mercury, it is essential to ensure cooperation from the consumers who generate mercury-containing waste. Continuous awareness-raising is a key to the successful collection and recycling of waste containing mercury. Encouraging public involvement in designing a collection and recycling system for waste containing mercury, which provides participating residents with information about the potential problems caused by the environmentally unsound management of such waste, would help to increase consumer awareness according to the Basel Technical Guidelines section L *on Awareness and Participation (*Basel, 2011*).*
- Crisis communication strategies should be developed and put in place from the start of a phase-out programme and may be used to address situations such as; the opening of a new production or recycling facility, or incidents that attract public attention or raise health concerns (UNEP, 2012).
- For more detailed information on public awareness campaigns, refer to section 6: Communications and Engagement in the Enlighten toolkit (UNEP, 2012).

9.1. Necessary information for users

- Users of mercury-containing lamps in private households should be given the necessary information about:
  - potential effects on the environment and human health as a result of the presence of hazardous substances, particularly mercury in mercury- containing lamps

   - Installation of mercury-containing lamps, e.g. CFLs should be handled carefully when installing or removing them and allowed to cool before touching the glass, and force should be applied to the ceramic or plastic base, not to the glass tube (UNEP, 2012).
   - The requirement of not to dispose of mercury-containing lamps as unsorted municipal waste and to collect such mercury-containing lamps separately;
   - The return and collection systems available to them detailed
   - Their role in contributing to reuse, recycling and other forms of recovery of mercury-containing lamps
- According to the UNEP Enlighten toolkit many successful campaigns focus on monetary savings, national pride, energy efficiency and energy savings, convenience (long-life), a simple switch, environmental responsibility, political and economic advantages. For more information , refer to section 6: Communications and Engagement in the Enlighten toolkit (UNEP, 2012).
- Some common FAQs and recommended responses can be found in section 6: Communications and Engagement in the Enlighten toolkit (UNEP, 2012).
- Publications should be translated into the locally relevant languages and dialects to ensure the information is communicated efficiently to the target population (Basel, 2011).

9.2. Clean up procedures information

- Refer to ANNEX A: clean up procedures in UNEP En-lighten toolkit, 2012.
- When a CFL is broken, the debris and mercury needs to be cleaned up, otherwise it remains in a room for an extended period of time (UNEP, 2012).
- The EU Ecodesign regulation requires manufacturers to provide information on their websites about how consumers should clean up debris in case of CFL breakage (UNEP, 2012). They must include a link to the online information on the packaging of each lamp.
- Tools for public awareness and participation
   - Refer to section L in the BASEL Convention technical guidelines section L on *Awareness and Participation* (Basel, 2011).

9.3. Roles and responsibilities

- Breakage education could be the responsibility of manufacturers and retailers alongside government campaigns however specific measurable targets would need to be defined along with a monitoring plan

References

1. BASEL Convention, 2011. BASEL Convention Technical Guidelines. Cartagena, Colombia, October 2011
2. NEP, 2012. Achieving The Global Transition To Energy Efficient Lighting Toolkit. ISBN:978-92-807-

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