هيئة مياه وكهرباء أبوظبي
Abu Dhabi Water & Electricity Authority

شركة العين للتوزيع
Al Ain Distribution Company

شركة أبوظبي للتوزيع
Abu Dhabi Distribution Co.

Manual on the Efficient Use of Electricity in the Government Sector

Disclaimer

Nothing in this manual should be construed as an endorsement of a particular manufacturer or supplier of energy equipment or their proprietary approach to energy efficiency. The intent of this manual is solely to provide Abu Dhabi government facility managers with guidance regarding major energy uses within a building and techniques to reduce such energy use, while maintaining the functionality of the building. The presence of any reference to a particular brand, manufacturer or model of equipment found in the hyperlinked references should be taken in the context of an illustration of a particular principle and not as a recommendation or endorsement for this equipment.

Acknowledgements

The development of this manual has been the joint effort of ADDC and AADC with discussions and valuable input from RSB and under the guidance of ADWEA and GSEC. We express appreciation to all those who have cooperated in this effort and recognize that the future energy savings to be realized from the use of the manual are a result of the knowledge, experience and passion provided in its development. The manual is only a first step, and the success of this energy reduction effort is dependent upon the cooperation and active involvement of all of the government entities who will make use of the information contained herein.

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Acronyms and Abbreviations

A/C	Air Conditioning
AADC	Al Ain Distribution Company
ADDC	Abu Dhabi Distribution Company
ADWEA	Abu Dhabi Water and Electricity Authority
ASD	Adjustable Speed Drive
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BTU	British Thermal Units
CCP	Comprehensive Cooling Plan
CFLs	Compact Fluorescent Lights
cm	centimeter
COP	Coefficient of Performance
DMA	Department of Municipal Affairs
DSM	Demand Side Management
DX	Direct Expansion
EC	Executive Council
EER	Energy Efficiency Ratio
ESMA	Emirates Authority for Standardization and Metrology
EVPD	Estidama Villa Products Database
GSEC	General Secretariat of the Executive Council
HID	High Intensity Discharge
HVAC	Heating, Ventilation, and Air Conditioning
IECC	International Energy Conservation Code
ISO	International Organization for Standardization
LEDs	Light Emitting Diodes
Lux	Measure of illuminance
m^2	meter squared
PM	permanent-magnet

QCC	Quality and Conformity Council
RTS	Radiant Time Series
rpm	revolutions per minute
UAE	United Arab Emirates
UPC	Urban Planning Council
VFD	Variable Frequency Drive
W	watts

1.0 Introduction

The Abu Dhabi government is aware of the need to reduce the consumption of electricity across all segments of society (e.g., residential, industrial, governmental) and is leading the way by implementing Demand Side Management (DSM) measures on all of its assets. This *Manual on Efficient Use of Electricity in the Government Sector* has been prepared in response to the Executive Council (EC) Decree No. 7 C 40/2015, dated 3 November 2015, pertaining to the development of a manual providing references and guidance for electricity-use reduction in governmental institutions.

This manual presents information and resources for facility managers for government buildings (offices and schools) on how to reduce electricity use throughout their buildings. The purpose of this manual is to help increase energy efficiencies and reduce the associated electricity costs of buildings in order to maximize building efficiency potentials. The following types of building systems and supporting activities are discussed:

1. **Space Cooling**
2. **Lighting**
3. **Building Envelope**
4. **Miscellaneous Electrical Equipment**
5. **Employee Awareness and Forums**

Individual measures are assessed for each type of building system. Throughout this document, the term “measure” refers to an electricity use saving effort or activity. Energy efficiency measures result in both electricity and monetary savings. Efficiency savings can often payback the efficiency investments in a few years, and can provide all of the energy savings to future energy bills thereafter. Maintenance methods are also presented for the facility manager for the different building systems.

1.1 Government Decrees and Directives for Electricity Consumption

Throughout 2015/2016, the Executive Council has issued a number of decrees to reduce wastage and enhance energy efficiencies in governmental operations across the Emirate. These decrees resulted in the government sector paying the full, unsubsidized cost of electricity and targeted the governmental sector with cooling and lighting reduction initiatives on all governmental facilities and properties.

The first decree (42 C 29/2015) was issued on 23 July 2015 and was aimed at directing the Chairman of the Department of Municipal Affairs (DMA) to coordinate with the Abu Dhabi Quality and Conformity Council (QCC) to study the best means to encourage the use of Light Emitting Diodes (LEDs) in residences and buildings throughout Abu Dhabi. Furthermore, this decree addressed the current standards of exterior street lighting in Abu Dhabi in order to include replacement criteria for the street lamps.

Shortly thereafter on 4 August 2015, the EC issued another decree (27 C 31/2015) requesting the General Secretariat of the Executive Council (GSEC) to coordinate with the Abu Dhabi Water and Electricity Authority (ADWEA), the Abu Dhabi Distribution Company (ADDC), the Al Ain Distribution Company (AADC), and other concerned bodies to create proposals and plans for increasing energy efficiency throughout the government sector.

This document is in response to the latest decree issued by the EC (7C 40/2015) on 3 November 2015, requesting ADWEA to issue a manual for facility managers in the governmental sector on electricity efficiency to assist the different government entities in identifying saving potentials and applying DSM measures to reduce electricity consumption. The latest issuance by the EC occurred on 13 January 2016 and set forth an instructional directive demanding all governmental sector properties and facilities to set back their thermostats (as discussed in **Section 2** of this document) and use smart lighting technologies (as discussed in **Section 3** of this document).

1.2 Manual Description

This manual provides the following information in each section:

1. Descriptions of each of the efficiency recommendations.
2. Textboxes in each section that provide link(s) accessing further guidance on the topics described throughout the manual. These sources have been selected to provide the reader with a comprehensive understanding of each topic and can be accessed by clicking on the textbox in the digital copy. References for the links can be found in the “Textbox References” section in **Appendix D**.
3. Protocols for the cooling and lighting surveys can be found in **Appendix B** and **Appendix C** respectively. Appendices also provide protocols for maintenance and references, as described throughout each section.

2.0 Space Cooling

ASHRAE Resources.

Air conditioning (A/C) is a necessity in the United Arab Emirates (UAE) due to the region's harsh climate. Past studies have indicated that A/C contributes to approximately over half of the total electricity consumption in Abu Dhabi Emirate.[1] There are various types of A/C systems, and plenty of methods to ensure that systems run as efficiently as possible. The following sections provide references for the different types of space cooling systems in Abu Dhabi and guidance on equipment upkeep and associated electricity usage and savings.

Although there are many "rules of thumb" in use regarding the estimation of cooling capacity for a particular building space, none of the rules provide accurate results for actual sizing of cooling equipment. The actual cooling load being served is a factor of many variables, including climate, building envelope, windows, ceiling height, lighting, and occupancy. An acceptable method for sizing cooling capacity for a particular space is the use of the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) standard 183-2007 (RA 2014) *Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings*. This methodology takes into consideration the aforementioned variables and more in order to develop a building-specific cooling capacity requirement. As a point of reference, an article in the January 2012 issue of the *ASHRAE Journal* uses the ASHRAE Radiant Time Series (RTS) Load Calculation Spreadsheet, found on the ASHRAE website, to estimate the cooling capacity required for a two-story office building in Kuwait City, Kuwait with 40% windows as 30 m^2 per ton.[2] In comparison, the application of an ASHRAE rule of thumb by the McDermott Group (a California-based Mechanical Engineer) to an office building located in the arid region of California produced 26 m^2 per ton.[3] It is recommended not to rely upon any rules of thumb, but to instead calculate the building-specific cooling capacity requirement.

2.1 Commercial Cooling Unit Types

High-Performance HVAC.

Cooling in Abu Dhabi can be grouped into two categories. The first category involves chilled water cooling systems, where water is chilled to a low temperature and

[1] RSB Powerwise. *How Can I Save Electricity: Air Conditioning.* (http://www.powerwise.gov.ae/en/section/how-can-i-save-electricity/residential/air-conditioning, Accessed May 2016).
[2] ASHRAE. *Load Calculation Spreadsheets.* (http://www.ashrae.org/, Accessed July 2016).
[3] McDermott Group. *Rule of Thumb HVAC Sizing.* (http://www.themcdermottgroup.com/Newsworthy/HVAC%20Issues/Rule%20of%20Thumb%20Sizing.htm, Accessed July 2016).

circulated to points in the building where the air is cooled through the use of a heat exchanger. The second category, direct expansion (DX) cooling, is where a refrigerant is cooled and circulated to points in the building where it cools the air.

The different types of cooling systems under each category include:

1. **Chilled Water Cooling Systems**
   a. **Individual Chiller Systems**
   b. **District Cooling Systems**
2. **DX Cooling Systems:**
   a. **Split Units**
   b. **Mini-Split Units**
   c. **Ducted Split Units**
   d. **Package Units**
   e. **Window A/C Units**

In order to ensure that A/C systems are running under optimal settings, facility managers must ensure that the A/C unit chosen is of the correct size and rating, has the appropriate motors, and is continuously maintained. In addition, to fully maximize the efficiency potential of the A/C units, thermostats (e.g., programmable, digital) should be installed in the building to control the indoor temperature throughout the day during different seasons.

2.1.1 Individual Chiller Systems

Chillers.
Chiller Efficiency.
Improving Chiller Efficiency.
Chiller System Balancing.

In 2013, a Comprehensive Cooling Plan (CCP) Building and Villa Survey conducted on 1000 buildings and 200 villas found that individual building chillers provide nearly half of the total cooling capacity across Abu Dhabi Emirate; therefore, optimal chiller design and operation in the Emirate is vital to reducing energy use. Most individual chiller systems in the Emirate's buildings and facilities use multiple rooftop air-cooled chillers.

Standard chillers use an evaporator, condenser, compressor, and an expansion valve for their operations. **Figure 2-1** displays a typical chiller system. The process associated with chilling is similar to that used in a refrigerator, where refrigerator fluid is heated and cooled using the evaporators and condensers. Standard chillers are mechanical

systems that use compressors and fans, and since most systems are located outdoors on roofs, they are subject to environmental wear and require regular maintenance and cleaning.

In addition, spatial restrictions can cause rooftop chillers to work inefficiently, such as when a chiller is too close to the parapet wall to allow free air to circulate around the chiller and condenser units. [5,6]

Figure 2-1: Chiller System[4]

The following five optimization measures have been found to be effective for optimizing chiller operation in Abu Dhabi:[7]

1. **Maintenance.** For information on maintenance, please refer to the prescribed protocol in **Appendix A-1**. It is advised that facility managers try to identify and deal with problems in advance of critical maintenance issues in order to help reduce future costs.
2. **System Balancing.** Chilled water pumps and the flow of chilled water from each chiller should be adjusted by a qualified Heating, Ventilation, and Air Conditioning (HVAC) engineer, as needed, to ensure to proper flow throughout the building.
3. **Refrigerant Charging.** The performance and efficiency of any A/C system depends highly on having the correct amount of refrigerant. This measure involves evacuating and weighing the system charge and adding refrigerant, as needed, to meet system specifications.
4. **Isolation.** Studies indicate that many chiller systems in Abu Dhabi are designed with a much higher cooling capacity than needed to adequately cool the building. Thus, building cooling loads should be analyzed by a qualified HVAC engineer to determine if one or more chillers are not needed.
5. **Variable Frequency Drives (VFDs).** Most of the chiller systems in Abu Dhabi are operated using constant-speed, chilled water pumps operating at a single speed. Operating all pumps at full power may be necessary during Abu Dhabi's summer season, but significant savings can arise if the pumps operate at lower speeds during other times of the year. Installing VFDs to assist in pump use allows the operator to run the chilled water pumps at lower optimum speeds to maximize system efficiency.

[4] Taken by RTI International for the Consolidated Pilot Program for Optimizing Chiller Performance in the Abu Dhabi Emirate, 2015.

[5] Cooling Technology, Inc. *Water Cooled Chillers & Air Cooled Chillers*. (http://www.coolingtechnology.com/about_process_cooling/water-cooled-chiller/default.html. Accessed May 2016.)

[6] Siemens. *How Does a Chiller System Work?* (http://www.industry.usa.siemens.com/automation/us/en/process-instrumentation-and-analytics/solutions-for-industry/hvacr/pages/how-does-a-chiller-system-work.aspx. Accessed May 2016.)

[7] According to the Consolidated Pilot Program for Optimizing Chiller Performance in the Abu Dhabi Emirate, 2015.

2.1.2 District Cooling Systems

What is District Cooling?
District Cooling Handbook.

Many new developments in Abu Dhabi Emirate run on district cooling systems. These systems use evaporators and condensers (heat exchangers or energy transfer systems) to distribute chilled water via pipelines to buildings for cooling purposes. Because multiple units rely on one centralized system, district cooling is considered an energy-efficient measure in Abu Dhabi. Buildings served by district cooling systems transfer the cooling from the chilled water pipes to the building A/C system through means of heat exchangers in multiple air handling units. The individual building is responsible for the operation and maintenance of the building air handlers, cold air distribution system, and return air exhaust systems. These cooling systems can often be made more efficient through the use of VFDs in place of conventional electric motors.

Since district cooling uses large chillers, facility managers should conduct maintenance and performance improvement continuously to ensure that the systems are optimized and balanced, refrigerant levels are within specifications, and pumps and motors are working efficiently. Because the cooling process occurs within a plant specifically designed and optimized for this single purpose, this should result in more efficient production of chilled water in large quantities. Pipelines that connect the district cooling system to its end-use locations also need to be maintained regularly and checked for wear and corrosion. Finally, systems and pipes need to be insulated to ensure there is no unnecessary heat gained from the surroundings.

2.1.3 DX Cooling Systems

Air Conditioners.

DX cooling systems are commonly found in villas, low-rise buildings, schools, shops, and some older high-rise buildings in Abu Dhabi. These systems come in two configurations. The first configuration is split systems, where the condenser and the compressor are located outside of the building and the evaporator is located on the inside. The other configuration is package systems, where all elements of the cooling system are packaged into a single unit that is located either on the roof or in the wall of the building. **Figure 2-2** provides figures and schematics of the common DX cooling systems used in government buildings. Non-chiller A/C units in governmental buildings in Abu Dhabi include the following:

1. **Split Systems.** These systems have a cooling capacity of 10 tons to over 100 tons and are designed to cool multiple rooms in a building by circulating

refrigerant to multiple heat exchanger units (e.g., fan coil units) inside the building.

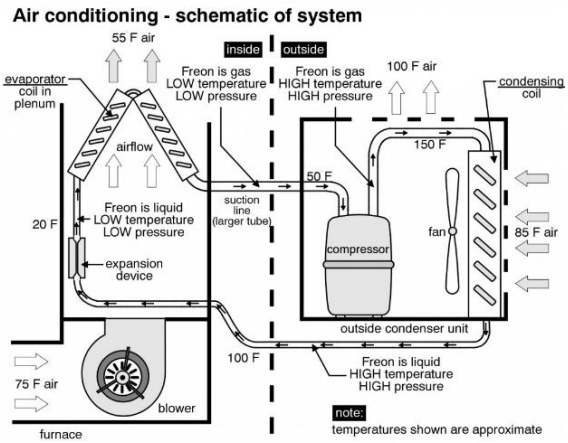
2. **Mini-split Units.** These A/C units operate on the same technology as the split systems, but have much smaller cooling capacity, on the order to 1 to 2 tons, and serve only a few fan coil units.
3. **Ducted Split Units.** These units are identical in cooling technology to the split systems. The delivery system is a heat exchanger system that cools the air, which is then distributed to the end-use location. The cooling capacity of ducted split systems range between 1 to several tons, depending on the cooling needs.
4. **Package Systems.** These systems range in cooling capacity from 3 to over 100 tons and are distinguished from other DX units in that the condenser, evaporator, compressor, and air handling unit are all self-contained in a single, usually roof-mounted package. The cooling unit is connected to ductwork that distributes cool air throughout the space to be conditioned.
5. **Window Units.** Although not common in governmental applications, window units (more properly “wall mounted” units) are sometimes used to cool small spaces such as guardhouses or small appending offices. The window unit is another type of “package” unit, in that the condenser, compressor, evaporator, and fan unit are all self-contained in a single package with a cooling capacity of 1 to several tons. Unconditioned air is brought in from the outside-facing portion of the unit, cooled, and then blown into the space to be conditioned.

Figure 2-2: DX Cooling Systems

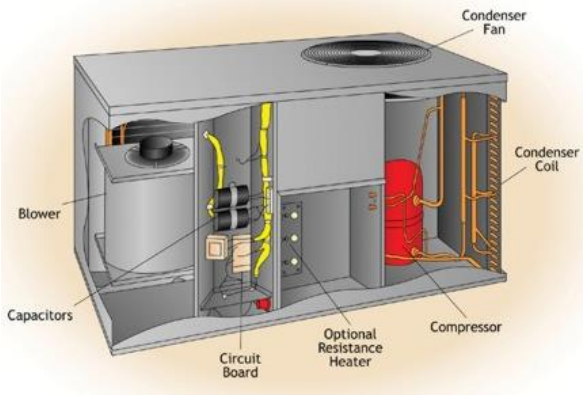
Split Systems[8]

Mini Split systems[9]

Schematic of a Ducted Split System[10]



Package Systems[11]



Appendices A.2- A.6 provide maintenance and repair protocols for several of the different types of DX cooling systems in Abu Dhabi. Typical maintenance procedures include checking the refrigerant levels, cleaning and/or replacing the air filters, and cleaning the condenser coils. The efficiency and life of the motor can be improved by re-filling the

[8] Carrier, *Commercial condensing unit/ air-cooled / mono-split. (*http://www.archiexpo.com/prod/carrier-commercial/product-49317-410375.html#product-item_41044, Accessed June 2016).

[9] Bright hub engineering, *Types of Air Conditioning Systems* (http://www.brighthubengineering.com/hvac/897-types-of-air-conditioning-systems/#imgn_1.jpg, Accessed June 2016).

[10] Hubpages, *Attic Central Air Conditioning: Energy Efficiency Information* (http://hubpages.com/living/Attic-Central-Air-Conditioning-Energy-Efficiency-Information#, Accessed June 2016).

[11] Ingram's Water and Air Equipment, *Package A/C* (http://www.system-selector.ingramswaterandair.com/packagedac.php, Accessed June 2016).

lubricants, checking the tightness of any belts, replacing any broken parts, and ensuring that all electrical connections are tight and insulation is not worn.

2.2 Cooling Unit Efficiency

Abu Dhabi has a few certification schemes for A/C systems and units. A/C efficiency is typically defined in terms of an Energy Efficiency Ratio (EER), which is the ratio between the cooling output (British Thermal Units per hour [BTU/hour]) to the power input (Watts [W]). A high EER is a good indicator of a highly efficient system.[12] Another measure of A/C efficiency is the Coefficient of Performance (COP), which is the ratio of heat removal (W) to energy input to the compressor (W), and is typically in units of watts/watts. Similar to the EER, the higher the COP, the higher the efficiency of the A/C system. The COP can be converted to EER by multiplying by a factor of 3.413, as 1 watt = 3.413 Btu/hour.[13,14]

QCC's Certification Schemes

Estidama: Buildings.

Estidama's A/C Equipment Guide.

Abu Dhabi International Building Codes.

ESMA Standards Store.

ISO 50001 Certification

The Abu Dhabi Quality Conformity Council is an Abu Dhabi government agency in charge of regulating and certifying products traded locally in Abu Dhabi.[15] In addition, Abu Dhabi's Urban Planning Council (UPC), which is involved in supporting Abu Dhabi's urban development strategy,[16] established the Estidama program that provides a sustainability framework for both new construction and existing buildings and certification requirements for a variety of electricity and water using technologies. The Estidama Villa Products Database (EVPD) also provides A/C equipment guidance for manufacturers and suppliers of A/C systems in the UAE. Although the database name suggests that it applies only to villas, the equipment suggested can act as a guidance for retrofits in governmental buildings as well because it has been approved by Estidama as compliant for energy efficiency. Please note that the QCC database is in the process of incorporating all of the EVPD information and will be the most current certification scheme available for energy-efficient products. Furthermore, the minimum Estidama requirements for certification were integrated into the Abu Dhabi International Building Codes, which is a building requirement database under the Abu Dhabi

[12] Energy Saver. *Room Air Conditioners.* (http://energy.gov/energysaver/room-air-conditioners. Accessed May 2016.)

[13] Business Dictionary.com. *Coefficient of Performance (COP).* (http://www.businessdictionary.com/definition/coefficient-of-performance-COP.html, Accessed July 2016).

[14] The Engineering Toolbox. *Cooling Load Converting – kW/ton to COP or EER.* (http://www.engineeringtoolbox.com/cop-eer-d_409.html, Accessed July 2016).

[15] Abu Dhabi Quality and Conformity Council. *About Us*. (http://www.qcc.abudhabi.ae/en/Pages/AboutUs.aspx?Main=About%20Us. Accessed May 2016).

[16] Urban Planning Council. *About Us*. (http://www.upc.gov.ae/about-us/overview.aspx. Accessed May 2016.)

Department of Municipal Affairs and Transport. The building codes provide the requirements for buildings to receive a construction permit.

The Emirates Authority for Standardization and Metrology (ESMA) was created in 2001 as the sole standardization body in the UAE.[17] A/C units in Abu Dhabi need to comply with the ESMA certification scheme for A/C systems for commercial and central A/C units. UAE.S 5010-5:2014 is the ESMA standard for energy efficiency for commercial and central air-conditioners, with different minimum EERs that will need to be met based on the different cooling capacities and types of A/C systems. The ESMA A/C certification rating scheme was initially established in 2011, and was then updated in 2014. Only the latest ratings should be considered when buying a new A/C system. ESMA standards can be purchased from the ESMA website.

Facilities can also become accredited for the International Organization for Standardization (ISO) certification relating to Energy Management Systems. ISO 50001-Energy Management is the certification scheme that applies to energy management. The objective of the ISO 50001 certification is to create an organizational structure to aid the facility in conserving electricity-using resources as well as saving money.

2.3 Periodic Maintenance

Chiller Maintenance.

HVAC Maintenance & Operation.

Periodic and preventative maintenance of cooling systems is vital for maintaining low electricity bills and maximizing energy reductions. Maintenance is needed for both chiller and non-chiller systems. **Appendix A** provides protocols for a complete maintenance assessment of an A/C system. Periodic maintenance should occur on at least a quarterly basis depending on the type of system being operated for the building. Frequency of maintenance can range between monthly, quarterly, bi-annually, and annually. It is recommended that during Abu Dhabi's peak summer months (June through September) that maintenance on A/C systems be conducted on a monthly basis, as A/C unit performance tends to deteriorate more frequently due to increased use and the higher temperature and humidity levels in the ambient environment.

[17] Emirates Authority for Standardization and Metrology. *About Us.* (http://www.esma.gov.ae/en-us/ESMA/Pages/About-ESMA.aspx, Accessed July 2016).

2.4 Motor Efficiency

Electric motors are used to run both the chiller and non-chiller A/C units, as well as pumps for circulating chilled water and blowers for circulating cold air. As shown in **Figure 2-3**, when motor efficiency is low, it can lead to large energy losses.

Rewinding Electric Motors.

Motor Energy Saving Tips.

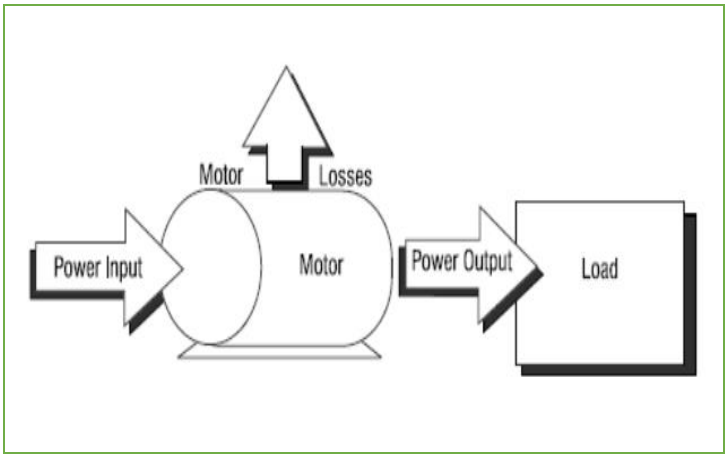
Efficient Electric Motors.

Motor Slip.

Some electrical power conservation strategies for motors include the following:[18,19]

1. **Purchasing Energy-Efficient Motors.** Many motor manufacturers provide energy-efficient alternatives to the standard efficiency motors offered in the market. Although an energy-efficient motor may be more expensive upfront, the associated electricity savings can make up for the cost over a minimal timespan. Purchasing motors with energy-efficient certifications aids in the reduction of electricity use.

Figure 2-3. Motor operation and losses[20]



2. **Proper Motor Sizing.** Many A/C units run inefficiently due to oversized motors being used to power a system. Purchasing the correct-sized motor (as described in the links provided in the textbox in this section) will aid the system's efficiency and lead to a reduction in the electric bill.
3. **Rewinding of Motors.** From a cost standpoint, it is often beneficial to rewind a motor before declaring it unusable. The link provided in the textbox at the beginning of this section outlines detailed information on rewinding motors.
4. **Variable Frequency Drives.** Refer to **Section 2.1.1** of this document for information regarding VFDs and their contribution to motor and pump efficiencies. This equipment, which is used to match speed to system demand, also goes by the term Adjustable Speed Drives (ASDs).
5. **Power Factor Correction.** Since electric motors operate on the basis of a magnetic field producing rotation of the motor's shaft, a portion of the power

[18] The University of Minnesota. (November, 2009). *Motor Energy Saving Tips*. (http://www.mntap.umn.edu/greenbusiness/energy/123-MotorTips.htm. Accessed May 2016).

[19] Electrical Engineering Portal. (September, 2014). *8 Energy Efficiency Improvement Opportunities In Electric Motors*. (http://electrical-engineering-portal.com/8-energy-efficiency-improvement-opportunities-in-electric-motors. Accessed May 2016).

[20] MRB Web Online. *Determining Motor Efficiency*. (http://www.mrb78.info/?page_id=14008, Accessed July 2016).

consumed is *reactive power* used to energize the magnetic coils, in addition to the *real power* that is used to perform the work produced by the motor. The combination of these two types of power produces the *apparent power* that is supplied to the motor and results in demand on the power system. The ratio of *real power* used to do work to the *apparent power* supplied to the motor is the power factor. The goal in energy efficiency is to correct for the *reactive power* in order to achieve as near as possible to a unity power factor. This correction can be done by adding capacitance to the feeder that is serving the combined motor loads.

6. **Reducing Voltage Imbalances.** In addition to power factor correction, ensuring that the rated voltage is being supplied to the motor can help increase both the efficiency and life of the motor. If needed, voltage controller equipment can be installed on the motor to ensure that the voltage is maintained appropriately.
7. **Motor Slip.** Motor slip is defined as the difference between the synchronous speed (the speed determined by the power supply frequency and the number of poles in the motor winding) of the motor and its actual shaft speed. Slip is measured in units of revolutions per minute (rpm) or frequency. Motor slip is a characteristic of an induction motor's design, and should be taken into consideration in the selection of the motor for a specific application. High-efficiency motors, such as synchronous, reluctance, or permanent-magnet (PM) motors have a smaller slip percentage than standard efficiency motors. [21, 22]

2.5 Thermostat Settings

Workplace Thermostats.

Thermostats are essential in controlling the indoor temperature of conditioned spaces and can significantly impact overall energy usage in a building. Due to the high levels of heat and humidity in Abu Dhabi, especially during the summer months, A/C units tend to operate continuously throughout the day. How much cooling is supplied by an A/C system is a factor of two elements—the temperature level setting of the thermostat and the amount of heat-gain experienced by the building through windows, doors, and building walls (see **Section 4** of this manual). The lower the set-point on the thermostat, the harder the A/C system needs to work and therefore the more energy it consumes. Electricity savings of up to 3% can be achieved for every degree increase in the set-point temperature.[23] Studies have verified that a thermostat setting of at least 24° C can provide an optimal balance between occupant comfort and energy efficiency.[24,25]

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[21] Electrical Construction & Maintenance. *Minimizing AC Induction Motor Slip.* (http://ecmweb.com/content/minimizing-ac-induction-motor-slip, Accessed July 2016).

[22] The Engineering Toolbox. *AC Variable Speed Drive.* (http://www.engineeringtoolbox.com/electrical-motor-slip-d_652.html, Accessed July 2016).

[23] California Energy Commission. *Summer Time Energy-Saving Tips.* (http://www.consumerenergycenter.org/tips/summer.html. Accessed June 2016).

[24] As per the Executive Council Decree (45C 01/2016).

[25] Dubai Electricity and Water Authority. (August 2014) *DEWA extends its 24°C campaign to the commercial sector.* (https://e-services.dewa.gov.ae/NewsHist/details.aspx?id=02433114000000000000000002433114, Accessed July 2016).

In addition to the temperature set-point of the thermostat, the time when space cooling is necessary provides another opportunity to reduce energy consumption. For optimal energy use without reducing occupant comfort, digital, programmable thermostats are recommended for installation. According to the time period when occupants are present, thermostats can be programmed to adjust the temperature, including increasing the temperature in unoccupied areas and returning to the "normal" temperature sufficiently prior to occupancy to condition the space for comfort. This practice has been proven to save energy in office buildings, as well as in homes much more so than by keeping a constant temperature throughout the day. Many thermostats available today have a sensing feature (similar to a lighting occupancy sensor) and a "learning" capacity such that they can detect usage patterns that can significantly reduce the amount of energy used for cooling by moderating the temperatures within unoccupied spaces. As a general rule, thermostats should be set to at least 24° C during a hot summer day, given that the closer the temperature is to the outdoor ambient temperature, the higher the energy savings.

2.6 Re-Commissioning

Recommissioning Buildings.

Re-commissioning, or retro-commissioning, involves evaluating and adjusting an existing building's equipment and systems for efficient performance, including energy use. Re-commissioning involves analyzing previously commissioned buildings (i.e., commissioned at the end of construction and prior to the building being put into use), while retro-commissioning analyzes buildings that have never before been commissioned or where the building has been changed from the original building commissioned configuration. The purpose of these programs is to address any issues that have occurred over a building's lifetime, and should be done periodically (semi-annually, annually, or seasonally) depending on the presence of a building maintenance program.[26] Re-commissioning is important to determine, in detail, the different operating conditions of all systems and allows for improvement in building operation systems. There are four phases involved in the re-commissioning process: planning, investigation, implementation, verification, and hand-off.

2.7 Cool Air Distribution

Air Distribution Systems.

Cool air distribution systems provide cooled air to different spaces within a building and are directly related

[26] Canmet Energy. (March 2008). *Recommissioning Guide for Building Owners and Managers*, *1st edition.* (http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/NRCan_RCx_Guide.pdf. Accessed May 2016.)

to occupants and their comfort levels. Therefore, it is important to maintain and conserve these systems in order to maximize efficiency and decrease energy costs. This involves evaluating many of the options previously discussed, or evaluating other technologies (e.g., fans, filters). The air distribution system should be optimized prior to upgrading the cooling system in order to maximize the building's energy potential. If an air distribution system is inefficient (e.g., if pipes are leaking or if the system is not appropriately sized), even the best A/C system will not run efficiently.

2.8 Impact of Lighting on Cooling

Lighting & HVAC.
Lighting & Cooling Loads.

Lighting directly impacts the cooling requirements of a room. When a lamp emits light, it also transfers heat into the surroundings. Inefficient lighting sources emit more heat per lumens of light into spaces, which leads to more A/C usage to counteract light-related heat emissions. A past study conducted in the UAE proved that replacing incandescent light fixtures with more efficient counterparts can lead to a 65% reduction in energy consumed by lighting and a 7% reduction in energy required to cool the space.[27] **Section 3** of this document provides proper guidance on lighting efficiency. It is recommended that efficient lighting retrofits be accomplished prior to A/C modifications to ensure that A/C potential is maximized and quantified accurately.

2.9 Cooling Survey

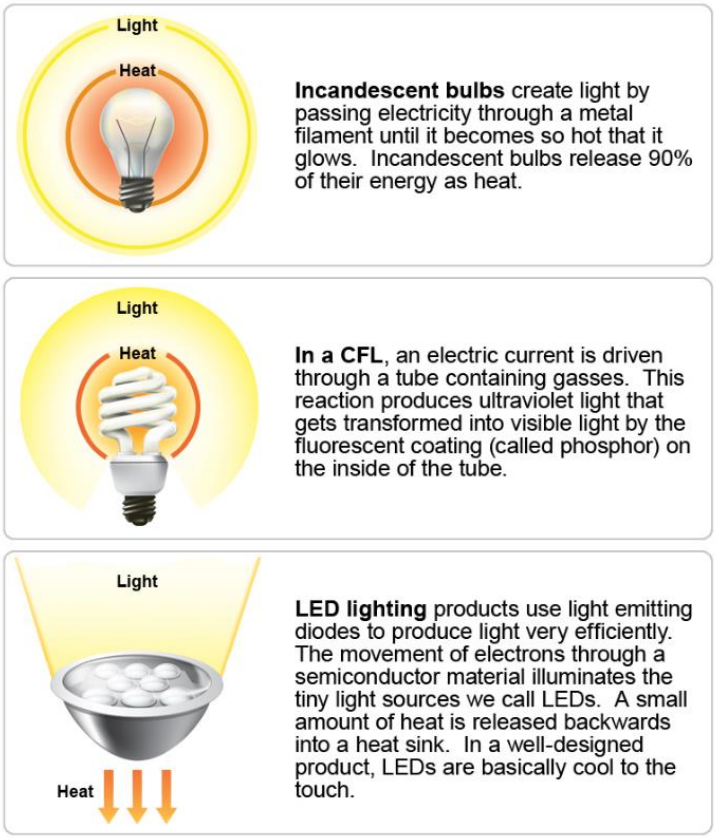
A facility manager can conduct a cooling survey to determine major energy using features, the opportunity for efficiency upgrades, and the need for a full-scale energy audit. A cooling survey should incorporate the key points provided in this manual. **Appendix B** provides guidance on significant items to look for in the survey, which should not take more than 1–2 hours, depending on the size of the facility's systems. The information collected from the cooling survey should then be provided to the electricity distribution company (ADDC or AADC). They will then use it to determine whether the facility is a candidate for a full energy audit which can identify measures that could be incorporated to reduce consumption.

[27] The Ecological Footprint Initiative. (December, 2014). *Benefits of Effective Implementation of the UAE's Lighting Regulation*. (http://d2ouvy59p0dg6k.cloudfront.net/downloads/auh_english_1.pdf Accessed May 2016.)

3.0 Lighting

Lighting utilizes approximately 15% of the energy consumed in an office building. [29] Modifying lighting technologies is therefore a proven method of reducing energy consumption in buildings. After cooling, lighting accounts for the next most significant portion of a building's electricity use and can maximize energy savings for a building quickly and easily.

Figure 3-1. Descriptions of how electricity is generates into light for each fixture[28]



Light fixture options typically range between incandescent light bulbs (the original form of the light bulb and a highly inefficient option), light emitting diodes (LEDs), or compact fluorescent lamps (CFLs). **Figure 3-1** provides a description of how each incandescent, LED, and CFL fixture generates light from the electric source. **Figure 3-2** on the following page provides a side-by-side comparison of the electricity use and the lifetime for the three different fixtures. LEDs and CFLs are the popular options worldwide to replace existing inefficient incandescent lamps. LEDs are becoming increasingly popular due to their long fixture life (LEDs can last up to 10 times longer than CFLs) and low operating costs, and new technologies have led to a decrease in their purchasing cost in the market. Although CFLs have been criticized over the years due to mercury contents in the lamps that can lead to environmental deterioration, they can be considered as an alternative to incandescent lamps provided they are disposed of properly.

[28] KQED Science. (July, 2013). *L.E.D. There Be Light.* (http://ww2.kqed.org/quest/2013/06/27/comparing-led-cfl-incandescent-light-bulbs-energy-saving/. Accessed May 2016).

[29] The British University of Dubai. (January 2016). *Building refurbishment strategies and their impact on saving energy in the United Arab Emirates.* (http://content.buid.ac.ae/events/Proceedings/SBE16D154.pdf, Accessed July 2016).

Figure 3-2. Comparison of incandescent, CFL, and LED electricity use and lifetime[30]

The UAE has recently passed new regulations for residential lighting products. These regulations ban all incandescent lamps and other products that do not meet the specified standards and prohibits the entry of incandescent bulbs for retail purposes as of 1 July 2014, with sales of the incandescent fixtures banned after 1 January 2015. As a result, future use of incandescent lamps in government buildings is not expected.

UAE Lighting Standards.

2013 Abu Dhabi International Energy Conservation Code.

Lighting O&M.

Energy Efficient Lighting.

Lighting.

In addition to inefficient lighting sources, Abu Dhabi's building occupants tend to waste electricity from lighting by keeping it on in unoccupied areas and by over-lighting portions of a building. The following sections act as a guide to facility managers on improving lighting efficiency in building interiors without decreasing lighting functionality.

Lighting illumination is another important factor to consider for efficiency and comfort. The Department of Municipal Affairs and Transport created the 2013 International Energy Conservation Code (IECC) for Abu Dhabi, which contains illumination recommendations for a variety of spaces. Illumination recommendations are presented as a part of this document based on the 2013 IECC, and the full list of illumination recommendations is provided in Table 505.5.2 "Interior Lighting Power Allowances" found on page 63 of the 2013 IECC for Abu Dhabi. [31]

[30] Inhabitat. (May, 2012). *How TO: Switch Your Light Bulbs And Get Ready for the Big Bulb Phase-Out.* Retrieved from http://inhabitat.com/how-to-switch-your-bulbs-to-leds-to-get-ready-for-the-incandescent-bulb-phase-out/time-line-phase-out/. Accessed May 2016.

[31] Department of Municipal Affairs and Transport. *International Energy Conservation Code* (https://municipalgateway.abudhabi.ae/en/About/Pages/buildingcode.aspx, Accessed July 2016).

Lighting fixtures require periodic maintenance, as necessary, including cleaning and replacement of the bulbs and ballasts. It is important to immediately disconnect light ballasts when the fixture has exceeded its use and replace the light fixture as soon as possible to maximize savings.

3.1 Lighting Sources – Offices: Enclosed

Lighting for Offices.

Office Lighting.

Business Lighting Technologies.

Various methods can be employed to improve lighting use in enclosed office spaces in Abu Dhabi; such improvements have been directly linked to an increase in worker productivity and public health. The 2013 IECC for Abu Dhabi recommends a brightness power allowance (lighting power density) of 10.8 watts per square meter (W/m^2) for an enclosed office plan.[32] Office lighting can be improved in a variety of ways, including, but not limited to, the following:

1. Replacing lighting fixtures with more efficient counterparts (e.g., LEDs, CFLs).
2. Using daylight through windows as a lighting mechanism instead of artificial light.
3. Adjusting workspace lighting, such as having an overhead light and/or a task light over your desk (see **Section 3.2** of this document).
4. Ensuring light brightness is appropriate.
5. Installing occupancy and/or ambient sensors (see **Sections 3.5 and 3.6**, respectively) to control lighting.
6. Having lights turned off when not needed and after working hours.

3.2 Lighting Sources – Offices: Open Plan

Office Lighting Design.

Task Lighting Facts.

As previously discussed, most workspaces in Abu Dhabi are over-lit, resulting in high electricity costs and energy use. Open plan offices can be adjusted easily for light use; the use of natural light through windows and/or a task light at a desk can decrease an electricity bill tremendously and can even result in higher worker productivity. Allowing each worker to control his or her individual lighting space (i.e., turn lights off as needed) and adding lighting controls can also aid in this initiative. In addition, adjusting light brightness in each room according to computer screen reflectivity and user comfort is a helpful measure. The 2013 IECC for Abu Dhabi recommends a brightness power allowance of 10.8 watts per square meter (W/m^2) for an

[32] Department of Municipal Affairs and Transport. *International Energy Conservation Code* (https://municipalgateway.abudhabi.ae/en/About/Pages/buildingcode.aspx, Accessed July 2016).

open office plan.[33] **Table 3-1** provides recommendations for different illumination levels for different tasks conducted in a workspace.

Table 3-1. Illumination recommendations for a variety of work activities[34,35,36,37]

Work Activity	Illuminance (Lux)[a]	Additional Info.
Computer	500–1000	—
Overhead Lighting	300–500	Recommended if no task light available.
Read standard document, photocopy, or newspaper	250–500	—
View photo in moderate detail; reference phone book	500–1,000	—
Performance of visual task of low contrast or small size over prolonged periods of time	2,000–5,000	—
Performance of very prolonged and exacting visual tasks	5,000–10,000	—
Performance of very special visual tasks of extremely low contrast and small size	10,000–20,000	—

[a] Lux is a unit of measure of illuminance, where 1 lux = 1 lumen/square meter. The lumen is a measure of light emitted from a source.

3.3 Lighting Sources – Common Areas

Lighting Interiors.

Areas occupied by multiple individuals (e.g., meeting rooms, hallways) also need to be considered for lighting needs. These areas should only be lit when in-use, and lighting brightness should be able to be adjusted according to the needs of the room. The 2013 IECC for Abu Dhabi recommends a brightness power allowance of 11.8 W/m^2 for a meeting room and 5.4 W/m^2 for a hallway (corridor).[32]

3.4 Lighting Sources – Specific Needs

Auditorium-Lighting Design.

Many government buildings in Abu Dhabi have conference rooms, auditoriums, or lecture rooms; these

[33] Department of Municipal Affairs and Transport. *International Energy Conservation Code* (https://municipalgateway.abudhabi.ae/en/About/Pages/buildingcode.aspx, Accessed July 2016).

[34] Lighting Deluxe. *Workplace Lighting: Best Practices for Office Lighting Design.* Retrieved from http://www.lightingdeluxe.com/workplace-lighting-ergonomics.html. Accessed May 2016.

[35] Canadian Centre for Occupational Safety and Health. *Eye Discomfort in the Office*. Retrieved from http://www.ccohs.ca/oshanswers/ergonomics/office/eye_discomfort.html. Accessed May 2016.

[36] Humanscale.com. *Task Lighting Solutions: Their Economic and Ergonomic Benefits.* Retrieved from http://www.humanscale.com/userfiles/file/tasklightingsolutions.pdf. Accessed May 2016.

[37] The Engineering Toolbox. *Illuminance – Recommended Light Levels* Retrieved from http://www.engineeringtoolbox.com/light-level-rooms-d_708.html. Accessed May 2016).

rooms are considered “Specific Needs” rooms as their lighting requirements are different than that in a hallway or office room. Typically, these rooms are quite large, seat a large group of people, and use a projector or video conference for presentation. These multi-purpose rooms need to be able to be adjusted for lighting on an individual use basis to maximize efficiency (e.g., the light can be shut-off while the screen light is on for presentations, and then turned on when there is more user interactions). The 2013 IECC for Abu Dhabi recommends a brightness power allowance of 6.5 W/m^2 for an auditorium, 11.8 W/m^2 for a conference room, and 14.0 W/m^2 for a lecture room.[38]

3.5 Occupancy Sensors

Occupancy Sensors.

Occupancy/Vacancy Sensors.

Occupancy sensors are necessary in buildings to control lighting in unoccupied spaces. Occupancy sensors have motion sensors are able to sense when someone walks into or leaves a room and can send infrared, ultrasonic, microwave, or other electronic sensor messages to the occupancy sensors, which then transmit the message via hardwire to the light sources to turn the light on/off accordingly. Installing occupancy sensors are an easy and cost-effective way to control lighting and reduce energy consumption in buildings.

3.6 Ambient Light Sensors

Ambient Light Sensors.

Ambient light sensors contain a technology that is able to detect the natural ambient light in an environment and adjust the artificial lighting provided in the space accordingly. Ambient light sensors are a cost-effective and efficient way to reduce energy use from lighting in a building, with significant window space transmitting ambient lighting.

3.7 Outdoor Lighting

Lighting.

Many government buildings have architectural (façade) lighting or exterior parking areas that require lighting. Outdoor lighting needs to be controlled similarly to indoor lighting, as described in the previous sections. The following items should be considered when choosing outdoor lighting systems:

[38] Department of Municipal Affairs and Transport. *International Energy Conservation Code* (https://municipalgateway.abudhabi.ae/en/About/Pages/buildingcode.aspx, Accessed July 2016).

1. Illumination levels.
2. Type of lighting fixture, including fixtures that provide whiter light sources.
3. Lighting controls, especially timers or ambient energy sensors, as previously described in **Sections 3.5 and 3.6**.

Outdoor light should be directed only where needed, glare should be minimal, and the illumination levels should be both appropriate and even.

3.8 Lighting Survey

Audit Toolkits.

Similar to a cooling survey, a lighting survey can be conducted by a facility manager to assess the lighting conditions in a governmental building. This survey would include a walk-through to assess the types of lighting systems throughout a building. It should be noted that every individual light fixture does not need to be evaluated, but the general lighting situation needs to be assessed.

The following items will need to be documented during a lighting survey: type of light fixture used in spaces such as offices, hallways, and auditoriums; the total number of lighting fixtures in each space (if available); lighting maintenance and repair protocols; lighting schedules; and the availability and setting of lighting controls. **Appendix C** provides guidance for items to look for during a lighting survey. The lighting survey should not take longer than 1-2 hours, depending on the size of the facility. As mentioned in **Section 2.9**, the information collected from this survey should then be provided to the electricity distribution company (ADDC or AADC). They will then use it to determine whether the facility is a candidate for a full energy audit which can identify measures that could be incorporated to reduce consumption.

4.0 Building Envelope

Building Energy.

Since the buildings subject to this manual have already been constructed, this section will review only low-cost building envelope retrofits. Building envelope measures include evaluating efficiency measures for the following in terms of insulation, window treatment, leaks, and any other environmental concerns:[39]

1. **Walls.** Further insulation can be added to exterior walls to minimize heat gain from the outdoor environment. In addition, caulking or weather-stripping sealants can be added to areas of infiltration (for example, in cracks or gaps of the exterior wall) to ensure no unnecessary outside heat can enter the premises.
2. **Windows.** Reflective window shades (such as reflective curtains, or insulating drapes) can replace current blinds/inefficient curtains to minimize heat gain through windows.
3. **Window Treatments.** Old window frames can be replaced with non-metal insulating window frames to reduce heat entry. If possible, replacing single-pane window glass with double- or triple-pane insulating glass is a recommended measure. Due to the Abu Dhabi heat, tinted glass/coatings is also an efficient measure to reduce heat gain into the building.
4. **Exterior Doors.** Installing revolving doors instead of standard swinging doors reduces heat infiltration and A/C losses from the building. This helps aid in cooling efficiencies in Abu Dhabi.
5. **Leaks.** Faulty weather stripping or installation can lead to leaks within a building's exterior walls. Fixing leaks is a guaranteed way to improve building efficiency.
6. **Roofs.** Heat gain to the building can be reduced through the use of reflective material (white stone or a light-colored reflective coating) applied to the roof area. Although this is not a substitute for adequate roof insulation, such "cool roof" technology can be applied to retrofit an existing building and has been shown to be effective in reducing the heat gain through the roof surface.

[39] National Renewable Energy Laboratory. *Saving Energy In Commercial Buildings.* Retrieved from http://www.nrel.gov/tech_deployment/pdfs/commercial_building_checklists.pdf. Accessed May 2016.

5.0 Miscellaneous Electrical Equipment

Office Equipment.
Office Audit Toolkits.

Many types of office equipment, such as printers, monitors, vending machines, and fax machines, are continuously plugged in and operating at all times in Abu Dhabi offices. Since the equipment is continuously consuming energy, even when not in use (a lot of this equipment is used minimally throughout a day), it leads to unnecessary energy costs and harmful air emissions. Much of the equipment is also kept on after working hours. Many new, highly rated machines come with Energy-Saving features that just need a few minutes to configure. This allows the equipment to enter a low-power or standby option when not in use (e.g., when users are away from monitors during lunch; printers throughout the workday). Referring to the owner's manual of the equipment can help determine if this an option for the office equipment in use.

Server rooms (where energy intensive computer equipment is located) also use a lot of energy. Better management of data storage and removing unused servers are simple ways for high savings for server rooms. Determining the number of pieces of equipment needed in an office for the particular office population and function is also necessary. Individual "private" printers in offices should be kept to an absolute minimum because they are additional sources of energy consumption that are sparingly used. When equipment is not being used regularly, in order to maximize savings, it should be shut down and only turned on when in use.

6.0 Employee Awareness and Forums

Employee Awareness In Energy Efficiency. Employee Awareness Campaigns.

Creating awareness campaigns for office tenants on how to improve the use of their office equipment and environment is vital for the success of electrical equipment efficiency measures. Awareness approaches can vary from flyers to brief seminars or emails and can contain information about how much electricity electronics are consuming, as well as electricity reducing measures. For example, employees need to be informed that they will need to switch their monitors off after leaving for the day in order to avoid unnecessary electricity wastage.

To execute an employee awareness program within a facility, the following items need to be addressed:[40]

1. **Team Assembly**: Commitment from senior managers, delegating an energy efficiency representative and program leader, and appointing an energy efficiency team are vital for the success of the program.
2. **Baseline Establishment:** Gathering information about how your facility uses energy in comparison to other facilities is important to understand how much of a reduction is needed.
3. **Objective Establishment:** Once the baseline is determined, establishing energy efficiency awareness and commitment objectives is the next step. Objectives include campaigns and employee behavioral changes.
4. **Promotion and Implementation:** The awareness program will need to be promoted through communication channels throughout the facility, and implementation of the program will need to be conducted through both these communication channels as well as regular activities throughout the program's lifetime.
5. **Evaluation:** Finally, the program's success will need to be determined. Determining the success of each objective and continuously benchmarking the facility to similar counterparts is vital to continually improve the program and achieve goals.

[40] Natural Resources Canada. *Implementing an Energy Efficiency Awareness Program* (https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/files/pdf/publications/commercial/Awareness_Program_e.pdf, Accessed July 2016).

Facility manager forums will be held by ADDC and AADC to discuss tips on how to engage employees in decreasing electricity usage in governmental facilities. The forums will aim to discuss the contents of this manual, will provide guidance on the next steps on the cooling and lighting surveys, will present the challenges faced by facility managers in Abu Dhabi, as well as will provide responses to any items of question to the facility manager. The forum will also provide guidance on employee awareness and marketing campaigns, in order for all facilities to meet their electricity reduction target by the needed timeframe.

Appendix A. A/C System Maintenance and Repair Protocols

Appendices A-1 through A-6 provide the following maintenance and repair protocols for A/C Units:

1. Appendix A-1: Chiller and District Cooling Systems Maintenance and Repair Protocols
2. Appendix A-2: Split A/C System Maintenance and Repair Protocols
3. Appendix A-3: Mini Split A/C System Maintenance and Repair Protocols
4. Appendix A-4: Ducted Split A/C System Maintenance and Repair Protocols
5. Appendix A-5: Package A/C System Maintenance and Repair Protocols
6. Appendix A-6: Window Unit A/C System Maintenance and Repair Protocols

Appendix A-1. Chiller System Maintenance and Repair Protocols

For Each Chiller:*

- Check refrigerant charge. Add refrigerant to the system if the levels are low.
- Check all refrigerant joints and valves for refrigerant leaks.
- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.
- Check chilled water flow switch operation.
- Check compressor oil level after the chiller has been operating at FULL LOAD for a minimum of 15 minutes. Check for compressor oil leaks, repair any leakage, and ensure that oil levels are correct.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check crankcase heater operation.
- Measure the suction and discharge pressure and compare to manufacturers charts.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check accuracy of thermistors. If there is a variance greater than 1.2 °C from calibrated thermometer, replace the thermistor.
- Verify that the chilled water loop is properly treated.
- Check refrigerant filter driers for excessive pressure drop. If there is a pressure drop, replace the filter driers.
- Check chilled water strainers, and clean the strainer system if it is dirty.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser.
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.

- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check for excessive cooler approach (Leaving Chilled Water Temperature — Saturated Suction Temperature), which may indicate fouling. Clean the cooler vessel if it is dirty.
- The condenser coils need to be cleaned as follows:
    - Chillers shall be shut down and allowed to cool for a minimum of 1 hour prior to cleaning of coils.
    - Condenser coils shall first be cleaned of all dust, fiber, and particulate material using a soft fiber (not wire bristle) brush.
    - All coils should then be cleaned from the inside out with an *Environmentally Sound Coil Cleaner* as described below.
    - *Environmentally Sound Coil Cleaner* should be a non-flammable, hypoallergenic, non-bacterial, biodegradable, and 100% ecologically safe agent that will not harm the coil or surrounding components such as electrical wiring, painted metal surfaces or insulation.
    - *Coil Cleaner* should be applied to all coil surfaces, including finned areas, tube sheets, and coil heaters, with a vertical up and down motion using a small (e.g., 9.5 liters) piston-pump pressurized garden-type sprayer followed by a water rinse with a low-velocity spray nozzle.
    - Ensure that the cleaner thoroughly penetrates deep into finned areas.

* *Refer to chiller manufacturers' recommendations for levels and set points.*

Appendix A-2. Split A/C System Maintenance and Repair Protocols

Outside Unit

- Check the casing for rust and other types of damage. Note that if the casing is damaged it could affect the operation of the unit.
- Check that the unit is properly mounted and anchored so that it does not move or shift when the compressor comes on.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser.
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.
- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check the compressor mount to ensure that it is solid and that anti-vibration pads are in place.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check for compressor oil leaks, repair any leakage, and ensure that oil levels are correct.
- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.

Indoor Unit

- Inspect heat exchangers in air handling units or individual fan coil units, whichever is used.
- Clean and straighten the evaporator coil fins, as needed.
- Check for and remove any obstructions to air flow.
- Check the blower alignment and balancing, and adjust, as needed. Clean the blower.
- Lubricate the blower motor.
- Check the electrical connections and wiring and repair, if needed.
- Clean air filters and replace any missing or damaged air filters.
- Check that the condensate pan drains properly. Clean the pan and drainage line.
- Check the accessible parts of the duct work for damage. Repair any openings at the joints where air leakage could occur.
- Check the condition of all thermostats. Set at an operating level of 24° C.

Operational Check, Maintenance, and Repair

- Turn on the A/C unit and allow at least 10 minutes for temperatures and pressures to stabilize.
- Check the functioning and accuracy of all thermostats, and repair or replace components, as needed.
- Check for adequate, unrestricted airflow to supply vents and diffusers.
- Measure and record the supply and return temperatures.
- Check the operation of the evaporator blower motor for bad or noisy bearings and replace, if defective.
- Check the operation of the condenser fan motor for bad or noisy bearings and replace, if defective.
- Check the operation of the compressor for evidence of wear or noisy bearings.
- Record the compressor operating voltage and current (amps), and compare to the manufacturer's specifications.
- Check the operating pressures and compare to the manufacturer's specifications.
- Check refrigerant lines for refrigerant leakage at all connections, worn areas, or cracks using soap bubbles, electronic leak detector, or other appropriate method. Repair all refrigerant leaks.

- After refrigerant leaks have been repaired, check the refrigerant charge using the Superheat Method or other appropriate method. Add refrigerant, if the unit is undercharged. If the unit is overcharged, withdraw refrigerant into a sealed container so that it does not escape to the atmosphere.
- If refrigerant system has been open (e.g., for compressor replacement), install new filter-driers, and check for refrigerant leaks at the filter-drier connections after installing the filter driers.

Appendix A-3. Mini Split A/C System Maintenance and Repair Protocols

Outside Unit

- Check the casing for rust and other types of damage. Note that if the casing is damaged it could affect the operation of the unit.
- Check that the unit is properly mounted and anchored so that it does not move or shift when the compressor comes on.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser.
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.
- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- Lubricate the fan motor and bushings.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check the compressor mount to ensure that it is solid and that anti-vibration pads are in place.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check for compressor oil leaks, repair any leakage, and ensure that oil levels are correct.

- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.

Indoor Unit

- Check that the unit is securely mounted, and check the control knobs for damage.
- Inspect heat exchangers in air handling units or individual fan coil units, whichever is used.
- Clean and straighten the evaporator coil fins, as needed.
- Check for and remove any obstructions to air flow.
- Check the blower alignment and balancing, and adjust, as needed. Clean the blower.
- Lubricate the blower motor.
- Check the electrical connections and wiring and repair, if needed.
- Clean air filters and replace any missing or damaged air filters.
- Check that the condensate pan drains properly. Clean the pan and drainage line.
- Check the accessible parts of the duct work for damage. Repair any openings at the joints where air leakage could occur.
- Check the condition of all thermostats. Set at an operating level of 24° C.

Operational Check, Maintenance, and Repair

- Turn on the A/C unit and allow at least 10 minutes for temperatures and pressures to stabilize.
- Check the functioning and accuracy of all thermostats, and repair or replace components, as needed.
- Check for adequate unrestricted airflow to supply vents and diffusers.
- Measure and record the supply and return temperatures.
- Check the operation of the evaporator blower motor for bad or noisy bearings and replace, if defective.
- Check the operation of the condenser fan motor for bad or noisy bearings and replace, if defective.
- Check the operation of the compressor for evidence of wear or noisy bearings.
- Record the compressor operating voltage and current (amps), and compare to the manufacturer's specifications.
- Check the operating pressures and compare to the manufacturer's specifications.

- Check refrigerant lines for refrigerant leakage at all connections, worn areas, or cracks using soap bubbles, electronic leak detector, or other appropriate method. Repair all refrigerant leaks.
- After refrigerant leaks have been repaired, check the refrigerant charge using the Superheat Method or other appropriate method. Add refrigerant, if the unit is undercharged. If the unit is overcharged, withdraw refrigerant into a sealed container so that it does not escape to the atmosphere.
- If refrigerant system has been open (e.g., for compressor replacement), install new filter-driers, and check for refrigerant leaks at the filter-drier connections after installing the filter driers.

Appendix A-4. Ducted Split A/C System Maintenance and Repair Protocols

Outside Unit

- Check the casing for rust and other types of damage. Note that if the casing is damaged, it could affect the operation of the unit.
- Check that the unit is properly mounted and anchored so that it does not move or shift when the compressor comes on.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser.
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.
- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- Lubricate the fan motor and bushings.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check the compressor mount to ensure it is solid and that anti-vibration pads are in place.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check for compressor oil leaks, repair any leakage, and ensure that oil levels are correct.

- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.

Indoor Unit

- Inspect heat exchangers in air handling units or individual fan coil units, whichever is used.
- Clean and straighten the evaporator coil fins, as needed.
- Check for and remove any obstructions to air flow.
- Check the blower alignment and balancing, and adjust, as needed. Clean the blower.
- Lubricate the blower motor.
- Check the electrical connections and wiring and repair, if needed.
- Clean air filters and replace any missing or damaged air filters.
- Check that the condensate pan drains properly. Clean the pan and drainage line.
- Check the accessible parts of the duct work for damage. Repair any openings at the joints where air leakage could occur.
- Check the condition of all thermostats. Set at an operating level of 24° C.

Operational Check, Maintenance, and Repair

- Turn on the A/C unit and allow at least 10 minutes for temperatures and pressures to stabilize.
- Check the functioning and accuracy of all thermostats, and repair or replace components, as needed.
- Check for adequate unrestricted airflow to supply vents and diffusers.
- Measure and record the supply and return temperatures.
- Check the operation of the evaporator blower motor for bad or noisy bearings and replace, if defective.
- Check the operation of the condenser fan motor for bad or noisy bearings and replace, if defective.
- Check the operation of the compressor for evidence of wear or noisy bearings.
- Record the compressor operating voltage and current (amps), and compare to the manufacturer's specifications.
- Check the operating pressures and compare to the manufacturer's specifications.

- Check refrigerant lines for refrigerant leakage at all connections, worn areas, or cracks using soap bubbles, electronic leak detector, or other appropriate method. Repair all refrigerant leaks.
- After refrigerant leaks have been repaired, check the refrigerant charge using the Superheat Method or other appropriate method. Add refrigerant, if the unit is undercharged. If the unit is overcharged, withdraw refrigerant into a sealed container so that it does not escape to the atmosphere.
- If refrigerant system has been open (e.g., for compressor replacement), install new filter-driers, and check for refrigerant leaks at the filter-drier connections after installing the filter driers.

Appendix A-5. Package A/C System Maintenance and Repair Protocols

Cooling Part of Unit

- Check the casing for rust and other types of damage. Note that if the casing is damaged, it could affect the operation of the unit.
- Check that the unit is properly mounted and anchored so that it does not move or shift when the compressor comes on.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.
- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- Lubricate the fan motor and bushings.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check the compressor mount to ensure it is solid and that anti-vibration pads are in place.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check for compressor oil leaks, repair any leakage, and ensure that oil levels are correct.

- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.

Air Handling Part of Unit

- Inspect attachment to building duct system for leaks or breaches in insulation and make repairs as necessary
- Clean and straighten the evaporator coil fins, as needed.
- Check for and remove any obstructions to air flow.
- Check the blower alignment and balancing and adjust, as needed. Clean the blower.
- Lubricate the blower motor.
- Check the electrical connections and wiring and repair, if needed.
- Clean air filters and replace any missing or damaged air filters.
- Check that the condensate pan drains properly. Clean the pan and drainage line.
- Check the accessible parts of the duct work for damage. Repair any openings at the joints where air leakage could occur.
- Check the condition of all thermostats. Set at an operating level of 24° C.

Operational Check, Maintenance, and Repair

- Turn on the A/C unit and allow at least 10 minutes for temperatures and pressures to stabilize.
- Check the functioning and accuracy of all thermostats, and repair or replace components, as needed.
- Check for adequate unrestricted airflow to supply vents and diffusers.
- Measure and record the supply and return temperatures.
- Check the operation of the evaporator blower motor for bad or noisy bearings and replace, if defective.
- Check the operation of the condenser fan motor for bad or noisy bearings and replace, if defective.
- Check the operation of the compressor for evidence of wear or noisy bearings.
- Record the compressor operating voltage and current (amps), and compare to the manufacturer's specifications.
- Check the operating pressures and compare to the manufacturer's specifications.

- Check refrigerant lines for refrigerant leakage at all connections, worn areas, or cracks using soap bubbles, electronic leak detector, or other appropriate method. Repair all refrigerant leaks.
- After refrigerant leaks have been repaired, check the refrigerant charge using the Superheat Method or other appropriate method. Add refrigerant, if the unit is undercharged. If the unit is overcharged, withdraw refrigerant into a sealed container so that it does not escape to the atmosphere.
- If refrigerant system has been open (e.g., for compressor replacement), install new filter-driers, and check for refrigerant leaks at the filter-drier connections after installing the filter driers.

Appendix A-6. Window Unit A/C System Maintenance and Repair Protocols

Cooling Part of Unit

- Check the casing for rust and other types of damage. Note that if the casing is damaged, it could affect the operation of the unit.
- Check that the unit is properly mounted and anchored so that it does not move or shift when the compressor comes on.
- Check that the electrical power disconnect is within sight of unit.
- Check the condition of the electrical power line, clean and tighten loose connections, and replace if the insulation is showing signs of wear.
- Check that the condenser has adequate clearance from obstructions to air flow. If there are moveable objects blocking condenser air flow, move them at least 60 cm away, if possible.
- Straighten the condenser coil fins, as needed. If the fins are too damaged to straighten, consider replacement of the condenser.
- Clean condenser fins. If the fins are slightly dirty, use a soft brush and/or vacuum; if they are very dirty, use a commercial coil cleaner and rinse with water.
- Check the condenser fan blades for cracks or damage. Replace any damaged fan blades. If the fan blades are bent, straighten them. If the fan blades are very dirty, clean them.
- Check that the fan motor shaft turns freely.
- Check condition of fan motor wiring and electrical connections. Clean and tighten any loose electrical connections. Replace any wiring with cracked or frayed insulation.
- Lubricate the fan motor and bushings.
- If the fan has a drive belt, check the belt condition and replace if it is cracked or worn. Also check the alignment of the belt and pulley and adjust them, if necessary.
- Check the compressor mount to ensure it is solid and that anti-vibration pads are in place.
- Check the compressor electrical connections to ensure tightness. Inspect wiring for signs of wear or insulation breakdown and replace as necessary.
- Check for compressor oil leaks, repair any leakage and ensure that oil levels are correct.
- Check the refrigerant line insulation and condition. Repair or replace damaged insulation.

Air Handling Part of Unit

- Clean and straighten the evaporator coil fins, as needed.
- Check for and remove any obstructions to air flow.
- Check the blower alignment and balancing, and adjust, as needed. Clean the blower.
- Lubricate the blower motor.
- Check temperature sensor; reposition, as the electrical connections and wiring and repair, if needed.
- Clean air filters and replace any missing or damaged air filters.
- Check control switch electrical connections for burned, frayed, or disconnected wiring and for loose connections, and repair, as needed.
- Check that the condensate pan drains properly. Clean the pan and drainage line.
- Check the accessible parts of the duct work for damage. Repair any openings at the joints where air leakage could occur.
- Check the condition of all thermostats. Set at an operating level of 24°C.

Operational Check, Maintenance, and Repair

- Turn on the A/C unit and allow at least 10 minutes for temperatures and pressures to stabilize.
- Check the functioning and accuracy of all thermostats, and repair or replace components, as needed.
- Check for adequate unrestricted airflow to supply vents and diffusers.
- Measure and record the supply and return temperatures.
- Check the operation of the evaporator blower motor for bad or noisy bearings and replace, if defective.
- Check the operation of the condenser fan motor for bad or noisy bearings and replace, if defective.
- Check the operation of the compressor for evidence of wear or noisy bearings.
- Record the compressor operating voltage and current (amps), and compare to the manufacturer's specifications.
- Check the operating pressures and compare to the manufacturer's specifications.
- Check refrigerant lines for refrigerant leakage at all connections, worn areas, or cracks using soap bubbles, electronic leak detector or other appropriate method. Repair all refrigerant leaks.
- After refrigerant leaks have been repaired, check the refrigerant charge using the Superheat Method or other appropriate method. Add refrigerant, if the unit is undercharged. If the unit is overcharged, withdraw refrigerant into a sealed container so that it does not escape to the atmosphere.

- If refrigerant system has been open (e.g., for compressor replacement), install new filter-driers, and check for refrigerant leaks at the filter-drier connections after installing the filter driers.

Appendix B. Cooling Survey Form (fill out one for each unit)

1. Type of Cooling Unit (check the box)

District Cooling	☐
Chiller	☐
Split DX System	☐
Package DX System	☐
Mini-Split System	☐
Ducted Split System	☐
Window Unit	☐

2. Capacity Rating of A/C Unit

_____ Tons *OR*

_____ kW

3. Efficiency Rating of A/C Unit

COP: _____ Watts/Watt *OR*

EER: _____ BTU/Wh

4. Type of Refrigerant (check the box)

R-22	☐
R-134	☐
R-134a	☐
R-410a	☐
R-12	☐
R-123	☐
R245fa	☐
R-407c	☐
R-417a	☐
Other:	_____

5. Age of A/C Unit (check the box)

< 1 year	☐
1-5 years	☐
5-10 years	☐
10-20 years	☐
> 20 years	☐

6. General Condition of outdoor A/C unit (compressors, pumps, etc.) (check the box)		
Good Condition =	No detectable leaks, all systems are working efficiently, system is clean.	☐
Average Condition =	Small leaks, systems are not working optimally, system maintenance has not been conducted routinely, system is slightly dirty.	☐
Bad Condition =	Many or large leaks, system is not properly maintained, system is very dirty, equipment is not working well, system needs to be replaced.	☐

7. Is this A/C unit controlled by a Building Automation System (a centralized digital system that controls temperature, airflow, hours of operation, etc.) or a simple thermostat?	
Building Automation System	☐
Thermostat	☐

Appendix C. Lighting Survey Form (fill out one for each room type)*

**Please note, individual fixtures in each room do not need to be analyzed. The purpose of this survey is to gain a general sense of the lighting situation in each building. For example, if one office is representative of all the offices in the building, then only one office will need to be surveyed in this phase, and a total number of offices be recorded. If that office is lit by the same type of fixture, only one fixture needs to be analyzed, and the total number of fixtures per office be recorded.*

1. Room Type

Office	☐
Common Area	☐
Corridor	☐
Conference Room	☐
Other	_____

2. Sample Room Size

_____ meters x _____ meters

3. Fluorescent Lighting Lamp Type *(if there are no fluorescent lights, skip to question 6).*

Fluorescent Tubes	☐
T-12	☐
T-8	☐
T-5	☐

4. Fluorescent Lighting Specifications

Size of Fixtures	_____ cm x _____ cm
Lengthwise Spacing Between Fixtures	_____ cm
Widthwise Spacing Between Fixtures	_____ cm

5. Ballast type used in fluorescent lights (if known)

Electronic	☐
Magnetic	☐

6. Other Lamp Type			
Type of Lamp Fixture		**Number of Fixtures**	**Fixture Rating (Watts [W])**
Incandescent	☐		
Compact Fluorescent Lamps (CFLs)	☐		
High Intensity Discharge (HID) - Mercury	☐		
HID - Sodium	☐		
HID - Halogen	☐		
LED Lamps	☐		
Other	_____		
7. Type of fixture			
Recessed	☐		
Surface Mount	☐		
Wall Mount	☐		
Other	_____		
8. Does this room have occupancy sensors to control the lighting?			
Yes	☐		
No	☐		

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