Date: 5 / 3 / 2017

Circular No. (3) for the year 2017

Regarding the Water and Electricity Consumption Rationalization Guide

In the headquarters and facilities of government entities in the Emirate of Abu Dhabi

To all government entities in the Emirate of Abu Dhabi

Peace be upon you and God's mercy and blessings...

We extend our warmest greetings and express our sincere thanks and appreciation for your continuous cooperation in achieving the public interest.

It is required to cooperate and coordinate with Abu Dhabi Distribution Company and Al Ain Distribution Company in rationalizing water and electricity consumption in the headquarters and facilities of the government sector in the Emirate of Abu Dhabi (according to the geographical scope) and to provide them with the following within one month from the date of issuance of this circular:

1. Conducting the initial field survey according to the requirements of the attached guide, and submitting a report clarifying the action plan and any shortcomings.
2. Determining the budgets and resources required to implement the requirements during the next year.
3. Preparing for participation in the distribution companies' programs designed to serve the government sector.
4. Appointing a contact point at the executive director level to follow up on the implementation and coordination of rationalization programs in your entity.

Appreciating your efforts and thanking you for your kind cooperation

For your action
May God grant you success..

Jassim Buataba Al Zaabi

Chairman of the Executive Committee

For inquiries, please contact Ms. Dina Muraish Saleh - Coordinator of the Water and Electricity Consumption Rationalization Program for the Government Sector - at telephone number 024161035 or via email dina.muraish@addc.ae.

• A copy of the guide is attached

Electricity Consumption Rationalization Guide

For Government Entities

Disclaimer

None of the contents of this guide should be taken as an endorsement of a specific manufacturer or supplier of any type of electrical equipment or the approach it follows in the field of efficient electricity use. This guide aims to provide some guidance to building managers of government entities in the Emirate of Abu Dhabi on the main uses of electricity in buildings and the necessary methods to reduce consumption without affecting the building's utility level. The mention of a specific brand or manufacturer listed in the hyperlinks in this guide should be treated as a model or example only, and not as advice to use or endorse a specific product.

Acknowledgment

Abu Dhabi Distribution Company and Al Ain Distribution Company have prepared this guide in consultation with the Regulation and Supervision Bureau for the Water and Electricity Sector in the Emirate of Abu Dhabi, and under the supervision of the Abu Dhabi Water and Electricity Authority. We extend our thanks to everyone who cooperated with us in this work and acknowledge that any level of electricity consumption reduction achieved through the application of what is stated in this guide is the result of the effort and expertise included in it. This guide is just a first step, and the success of efforts to reduce electricity consumption is based on effective cooperation among all government entities that will work to benefit from the information contained in this guide.

Contents

Appendices

List of Figures

List of Tables

Introduction

The Abu Dhabi government recognizes the importance of rationalizing electricity consumption across all segments of society, including the residential, industrial, and government sectors. Based on this, the government is implementing a demand-side management program for electricity in all its buildings, institutions, and assets. In light of this, the "Guide for Efficient Use of Electricity in the Government Sector" was prepared in response to the Executive Committee's resolution No. (7 C 2015/40) issued by the Executive Council on November 3, 2015, regarding the preparation of a guide to provide technical directives and guidance for reducing electricity consumption in government entities.

The guide provides information and resources for managers of government facility buildings (such as offices and schools) on how to reduce electricity consumption in these buildings. The guide aims to help improve electricity usage efficiency and reduce the associated costs to enhance the expected return from these buildings. This guide addresses the following types of building systems and their supporting activities:

1. Air Conditioning
2. Lighting Systems
3. Building Envelope
4. Miscellaneous examples of electrical appliances
5. Raising employee awareness levels

The measures that can be applied to each building are evaluated from the perspective of the person responsible for the maintenance and operation of these buildings. The term "measures" in this guide refers to the various efforts aimed at rationalizing electricity consumption. Measures aimed at improving consumption efficiency lead to electricity savings and a reduction in the associated economic costs at the same time. The savings resulting from the efficient use of electricity may cover the expenses of these measures within a few years and may lead to saving the total amounts that could be spent on future electricity bills. The guide also provides an explanation of the maintenance methods that can be applied to various types of building air conditioning systems.

Government Directives on Electricity Consumption in the Emirate of Abu Dhabi

The Executive Committee's resolution No. (42 C 2015/29) was issued on July 23, 2015, directing the Department of Municipal Affairs and Transport to coordinate with the Abu Dhabi Quality and Conformity Council to study the best ways and means to encourage everyone to use energy-saving Light Emitting Diode (LED) lighting systems in the residences and buildings of the Emirate of Abu Dhabi. The resolution also addressed the current standards used for street lighting in the Emirate of Abu Dhabi with the aim of developing specifications for replacing the lamps used on roads.

On August 4, 2015, the Executive Committee issued Resolution No. (27 C 2015/31) to direct the General Secretariat of the Executive Council to coordinate with the Abu Dhabi Water and Electricity Authority, Abu Dhabi Distribution Company, Al Ain Distribution Company, and other concerned entities to develop proposals and plans to increase the efficiency of electricity consumption in the government sector.

This guide came in response to the resolution issued by the Executive Committee (7 C 2015/40) on November 3, 2015, to direct the Abu Dhabi Water and Electricity Authority to prepare a guide for rationalizing electricity consumption for government entities on the efficient use of electricity to help various government entities identify their potential for rationalizing consumption and implementing the procedures of the demand-side management program. Another follow-up resolution, No. (45 C 1 / 2016), was issued on January 13, 2016, setting directives for government sector facilities to lower the setpoint of their air conditioning thermostats and use smart lighting technology systems.

Guide Description

Each section of this guide provides the following information:

1. Explanation of the recommendations provided to achieve efficient use of electricity.
2. Hyperlinks for more guidance on the topics discussed in the guide. These sources have been chosen to give the reader comprehensive information on each topic and can be accessed by clicking on the text in the electronic version. These links can be found in "Appendix D" for "References".
3. Forms for studying cooling and lighting systems can be found in "Appendix B" and "Appendix C" respectively. These appendices also provide maintenance protocols and references as they appear in each section under Appendices A(1) to A(6).

Air Conditioning

ASHRAE Resources

The presence of air conditioning is essential in the United Arab Emirates today due to the harsh climatic conditions and high temperatures in this region of the world. Previous studies have shown that air conditioning systems consume more than half of the electrical energy consumed in the Emirate of Abu Dhabi. There are many types of air conditioners and many ways and means to help ensure these devices operate as efficiently as possible. The following sections provide some information about the different types of air conditioners used in Abu Dhabi and some guidance on their maintenance, their electricity consumption, and how to increase their efficiency to reduce consumption.

Although there are many "rules of thumb" for estimating the required cooling capacity for each building based on its area, none of these rules provide accurate information about the required size of air conditioning units. The required cooling capacity is determined based on many variable factors including climate, building insulation, windows, internal ceiling height, lighting, and occupancy.

The best method to determine the required cooling system size is to use the standards set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2007-183 under the name "Peak Cooling and Heating Load Calculations for Buildings Except Low-Rise Residential Buildings". This method takes into account the previously mentioned variables and other factors to determine the required cooling capacity for each building according to its size. As a reference document, the society's journal published an article in its 2012 edition titled "The ASHRAE Radiant Time Series (RTS) Load Calculation Spreadsheet," available on the society's website, about calculating the required cooling capacity for a two-story building in Kuwait City where windows cover 40% of its wall area. Accordingly, every 30 square meters requires one ton of cooling capacity. By comparison, the use of the society's standards by the McDermott Group, a mechanical engineering firm based in California, in an office building in the dry region of California showed that every 26 square meters requires one ton of cooling capacity. Therefore, it is better

not to rely on fixed rules but to calculate the air conditioning requirements for each building independently.

Regulation and Supervision Bureau, Powerwise, How Can I Save Electricity?, Air Conditioning, accessed May 2016 (http://www.powerwise.gov.ae/en/section/how-can-i-save-electricity/residential/air-conditioning)

ASHRAE Load Calculation Spreadsheet, accessed July 2016 https://www.ashrae.org/

The McDermott Group: Rules of Thumb for Sizing High-Voltage Air Conditioning Systems, accessed July 2016 [http://www.themcdermottgroup.com/Newsworthy/HVAC%20issues/Rule%20of%20Thumb%20Sizing.htm]

Types of Commercial Air Conditioning Units

Heating, Ventilation, and Air Conditioning (HVAC) Systems

Air conditioning units used in Abu Dhabi are divided into two categories: the first operates by cooling water to a low temperature and then passing it through specific locations in the building where the air is cooled via a heat exchanger. The second category uses a direct expansion system, which involves cooling a refrigerant and then passing it to specific locations in the building to cool the air.

The different cooling systems under each of the two categories consist of the following types:

1. **Water-Cooled Systems:**
    a- Central Chiller Systems
    b- District Cooling Systems
2. **Direct Expansion Systems:**
    a- Split Air Conditioning Units
    b- Mini-Split Air Conditioning Units
    c- Ducted Split Air Conditioning Units
    d- Packaged Air Conditioning Units
    e. Window Air Conditioning Units

To ensure optimal operation of air conditioning systems, facility managers must ensure that the selected air conditioning unit is of an appropriate size and scale, equipped with suitable pumps, and maintained periodically. To use air conditioning units effectively, a thermostat (for example, a programmable digital device) must be installed in the building to control the internal temperature throughout the day and different seasons.

Central Chiller Systems

Chillers

Chiller Efficiency

Improving Chiller Efficiency

Balancing Cooling Systems

In 2013, a comprehensive study was conducted in the Emirate of Abu Dhabi on air conditioning systems in buildings and villas, covering 1000 buildings and 200 villas. It showed that central chillers constitute half of the air conditioning systems used in almost all areas of the Emirate. Therefore, using high-efficiency cooling systems is essential for reducing electricity consumption in the Emirate. Most central chiller systems used in buildings and facilities in the Emirate use multiple air conditioning systems placed on the roofs of buildings.

Standard cooling systems use an evaporator, a condenser, a compressor, and an expansion valve in their operations. Figure 1-2 shows a typical air conditioning system in Abu Dhabi. The process used in this type of air conditioning system is similar to that of refrigerators, where the refrigerant gas is heated and cooled by evaporators and condensers. Standard air conditioners of this type are mechanical systems that use multiple compressors and fans. Since most of these systems are placed in exposed locations on building roofs, they are subject to natural elements and require periodic maintenance and cleaning.

Additionally, space constraints may cause rooftop air conditioners to not work well, such as placing the air conditioner near the parapet wall at the edge of the roof, which leaves no room for air to pass through to cool the unit and its condenser units. The following five measures have proven effective in increasing the efficiency of central chiller systems in Abu Dhabi:

Figure 1-2 Central Chiller Units

Taken from the RTI International Pilot Project for Improving the Efficiency of Central Chiller Units in the Emirate of Abu Dhabi 2015

Cooling Technology Institute: Water-Cooled Air Conditioning Systems and Air-Cooled Air Conditioning Systems [http://www.coolingtechnology.com/about_process_cooling/water-cooled-chiller/default.html, Accessed May 2016.]

Siemens: How do water-cooled air conditioning systems 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).

RTI International Pilot Project for Improving the Efficiency of Central Chiller Units in the Emirate of Abu Dhabi 2015

1. **Maintenance:** For information on maintenance operations, please see the protocol in Appendix A-1. Building managers are advised to identify and deal with problems before major maintenance issues arise, which helps reduce future costs.
2. **Re-balancing and Commissioning of AC Systems:** The chilled water pumps and their flow from each chiller must be balanced by a qualified HVAC engineer to ensure a balanced water flow throughout the building.
3. **Refrigerant Recharging:** The performance and efficiency of any cooling system largely depend on having the proper refrigerant charge. This requires removing, weighing, and refilling the refrigerant and adding refrigerant as needed to meet the unit's requirements.
4. **Isolating Excess Capacity:** Studies have shown that many air conditioning systems used in Abu Dhabi are oversized for the building's actual needs. Therefore, a qualified engineer should be consulted to analyze the air conditioning systems to determine if one or more of the water chillers used are truly needed.
5. **Variable Frequency Drives (VFDs):** Most water cooling systems in Abu Dhabi operate at a single, constant speed, meaning the chilled water pumps run at a constant speed all the time, regardless of the actual cooling system needs. It may be necessary to run all pumps at their maximum capacity during the summer in Abu Dhabi, but a lot can be saved if they are run at a lower speed during other times of the year. Therefore, installing a VFD to assist with pump operation allows the user to run the chilled water pumps at a lower speed, thus maximizing the cooling system's efficiency.

District Cooling Systems

Many new buildings in Abu Dhabi use district cooling systems equipped with water evaporators and condensers, heat exchange systems, or energy transfer systems, to distribute chilled water through pipes to cool buildings in a specific geographical area. Because this system has multiple air conditioning units relying on a single central system, this type of system is considered energy-efficient in Abu Dhabi. Buildings equipped with district cooling systems are cooled by transferring coolness from the chilled water pipes to the air conditioning system through heat exchangers located in multiple air handling units. A person is responsible for the operation and maintenance of the cool air transfer and distribution devices and the exhaust air systems. The efficiency of these systems can be increased by using variable frequency drives instead of traditional electric motors.

Since district cooling systems use large-sized water chillers, maintenance personnel must perform ongoing maintenance and performance improvements to ensure these systems operate optimally and in a balanced manner, that the refrigerant is at the required level according to specifications, and that pumps and motors are operating efficiently. Since the cooling process takes place in a device specifically designed for this purpose, this will lead to the production of chilled water in large quantities. The pipes connecting the central air conditioning unit to the location to be cooled also need periodic maintenance and inspection to ensure they are free from any damage or corrosion due to rust. Finally, these pipes must be covered with thermal insulation to ensure no heat leaks from the outside.

Direct Expansion Systems

Air Conditioners

This type of air conditioner is commonly used in villas and low-rise buildings such as schools and shops, and in some older high-rise buildings. These systems are divided into two types: the first is split units, where the condenser and compressor are placed outside the building while the evaporator is inside. The second type is the packaged system, where all elements of the air conditioning system are in a single unit placed either on the roof of the building or on the wall. Figure 2-2 shows the form and composition of direct expansion systems widely used in government buildings. Air conditioning units that do not use water cooling units in government buildings in Abu Dhabi include the following:

1. **Split Air Conditioning Units:** The cooling capacity of these systems ranges from 10 tons to more than 100 tons and they are designed to cool multiple rooms in a single building by circulating refrigerant through a number of multiple heat exchange units inside the building.
2. **Mini-Split Air Conditioning Units:** These cooling units operate with the same technology as split air conditioning units but have a lower cooling capacity, ranging from only 1 to 2 tons, and use a few fan coils.
3. **Ducted Split Air Conditioning Units:** These units are similar to split air conditioning units where the heat transfer system is a heat exchanger that cools the air which is then distributed to the areas to be cooled. The cooling capacity of these systems ranges from one ton to several tons, depending on the area to be conditioned.
4. **Packaged Air Conditioning Units:** The capacity of these systems ranges from 3 to 100 tons and they are distinguished from direct expansion units in that the condenser, evaporator, compressor, and all other units are placed in a single unit, usually on the roof of the building. This unit is connected to ducts that distribute cool air in the building to cool it.
5. **Window Air Conditioning Units:** Although not widely used in government buildings, window air conditioning units are sometimes used to cool small-area buildings such as guard rooms or small

attached offices. They are another type of packaged system where the condenser, compressor, evaporator, and fan are all in one unit, with a cooling capacity ranging from one ton to several tons. This type of system draws hot air from the outside, then cools and pushes it into the building to be conditioned.

Figure 2-2: Direct Expansion Systems

Mini-Split Air Conditioning Units

Indoor Unit

Outdoor Unit

Split Air Conditioning Units

Packaged Air Conditioning Units

Ducted Split Air Conditioning Units

Air conditioning - schematic of system

Appendix A-2 to Appendix A-6 provide maintenance and repair protocols for a number of different types of direct expansion air conditioning systems in Abu Dhabi. Optimal maintenance procedures include checking refrigerant levels, cleaning or replacing the air filter, and cleaning the condenser. The efficiency and lifespan of the motor can be increased by replacing the oil, ensuring the fastening belts are tight, replacing broken parts, and ensuring that all electrical wires and connections are securely fastened and that the insulating materials are in good condition.

Carrier Commercial Condensing Units / Air-Cooled Single Split Units, accessed June 2016 (http://www.archiexpo.com/prod/carrier-commercial/product-49317-410375.html#product-item_41044)

Bright Hub Engineering, Types of Air Conditioning Systems. accessed May 2016 (http://www.brighthubengineering.com/hvac/897-types-of-air-conditioning-systems/#imgn_1.jpg)

HubPages, Attic Central Air Conditioning, Energy Efficiency Information. accessed June 2016 (http://hubpages.com/living/Attic-Central-Air-Conditioning-Energy-Efficiency-Information#)

Ingram's Water and Air Equipment, Packaged Air Conditioning Units (http://www.system-selector.ingramswaterandair.com/packagedac.php) accessed June 2016.

Air Conditioning System Efficiency

Abu Dhabi Quality and Conformity Council Certificates

Estidama: Buildings

Estidama Guide for Air Conditioning Equipment

Abu Dhabi International Building Codes

Emirates Authority for Standardization and Metrology (ESMA) Specifications Store

ISO 50001 Certification

The efficiency of air conditioners is defined by the Energy Efficiency Ratio (EER), which is the ratio of the amount of cooling produced to the energy consumed. The higher the EER, the better the efficiency of the air conditioning system. Another measure to evaluate the efficiency of a cooling system is the Coefficient of Performance (COP), which is the ratio of heat extracted to the amount of energy required to compress the air, calculated in watts per watt. Like the EER, the higher the COP, the higher the efficiency of the air conditioning system. COP can be converted to EER by multiplying it by a factor of 3.413, i.e., 1 Watt = 3.413 BTU/hour.

The Abu Dhabi Quality and Conformity Council (QCC) is responsible for regulating and licensing all products sold in Abu Dhabi markets, using a quality mark as one of the means to ensure the high efficiency of devices traded in Abu Dhabi markets. Additionally, the Abu Dhabi Urban Planning Council, which is responsible for setting the strategic plan for urban development in the Emirate, has launched the Estidama program, which provides a general framework for sustainability applied to existing and new buildings and issues certificates of accreditation for a number of electricity and water equipment. The "Estidama Villa Product Database" provides guidance to manufacturers and suppliers of air conditioning systems operating in the country. Although the devices listed in this list suggest that this equipment is intended for use in villas only, it can be used for modifications to equipment used in government buildings because it is certified by Estidama as being energy efficient. Work is currently underway to expand the QCC database to include all the information contained in the "Estidama Villa Product Database" to become

the latest available system for high-efficiency energy products. Furthermore, the requirements of the Estidama program have been included in the Abu Dhabi Building Codes system, which is a database of requirements for issuing building permits in the Emirate of Abu Dhabi and is managed by the Department of Municipal Affairs and Transport.

Energy Saver, Room Air Conditioners (http://energy.gov/energysaver/room-air-conditioners) accessed May 2016

BusinessDictionary.com, Coefficient of Performance (COP) (http://www.businessdictionary.com/definition/coefficient-of-performance-COP.html) accessed July 2016

The Engineering Toolbox, Cooling Load Conversion (http://www.engineeringtoolbox.com/cop-eer-d_409.html) accessed July 2016

About Abu Dhabi Quality and Conformity Council (QCC) (http://www.qcc.abudhabi.ae/en/Pages/AboutUs.aspx?Main=About%20QCC) accessed May 2016

About the Urban Planning Council (http://www.upc.gov.ae/about-us/overview.aspx) accessed May 2016

The Emirates Authority for Standardization and Metrology (ESMA) is the sole body authorized to set standards in the UAE. Air conditioning units sold in Abu Dhabi and used for commercial or central purposes must obtain a certificate of accreditation from this authority with different minimum levels for the EERs standard based on different cooling capacities and types of devices. The authority established its certification system in 2011 as a first step, then it was amended in 2014, so the latest amendment must be adopted when purchasing any air conditioning unit. This system can be purchased from the authority's website.

Government institutions can also obtain international ISO certifications related to energy management systems, such as ISO 50001 for energy management, aimed at helping them establish management systems that help rationalize electricity consumption and thus achieve some economic savings.

Periodic Maintenance

Chiller Maintenance

HVAC Systems Operation and Maintenance

Periodic and preventive maintenance of air conditioners is of great importance for reducing the cost and consumption of electricity and increasing efficiency. Maintenance is necessary for water-cooled, central, and other types of air conditioners. Appendix A provides protocols for comprehensive maintenance of any air conditioning unit. Periodic maintenance should be carried out every three months based on the type of air conditioning unit used in the building, and the maintenance period ranges from one month to every three months, every six months, or once a year. It is recommended to perform monthly maintenance during the summer in Abu Dhabi, from June to September, because the performance of these devices decreases more due to increased use and high levels of heat and humidity during this period of the year.

Motor Efficiency

Electric Motor Rewinding

Motor Energy Saving Tips

Efficient Electric Motors

Electric motors are used to operate cooling units and other equipment, pumps are used to

Difference between Input Power and Motor Speed distribute chilled water, and fans are used to distribute air. Figure 2-3 shows that when motor efficiency decreases, it leads to a significant waste of energy.

About the Emirates Authority for Standardization and Metrology (ESMA) (http://www.esma.gov.ae/en-us/ESMA/Pages/About-ESMA.aspx) accessed July 2016

Some strategies for rationalizing the electricity consumed in operating motors include the following:

1. **Using high-efficiency electric motors.** Many motor manufacturers offer high-efficiency alternatives. Although the initial cost of purchasing these devices may be high, it can be offset by lower electricity consumption costs within a short period. Acquiring a motor with an energy efficiency certificate helps reduce electricity consumption.
2. **Appropriate motor size:** Many air conditioners operate less efficiently due to using a motor that is larger than their actual need. Therefore, using a properly sized motor, as shown in the links listed here, will help the air conditioner operate efficiently and lead to a reduction in the electricity bill.
3. **Motor rewinding:** From an economic perspective, it is sometimes better to rewind a motor before considering it unusable. The link in the box above provides detailed information about the motor rewinding process.
4. **Variable Frequency Drives (VFDs):** Please refer to point (5) under the Central Chiller Systems section of this guide for information on VFDs and the role they play in increasing motor and pump efficiency. This device, used to adjust the speed of the air conditioner to match the actual need, is called a speed controller.
5. **Power factor correction:** Since electric motors operate via a magnetic field that causes the motor shaft to rotate, part of the energy consumed in this process is reactive power used to move the magnetic parts, in addition to the real power used to perform the motor's function. The sum of these two types of power produces the apparent power that supplies the motor and places a demand on the power system. The ratio of the real power used

University of Minnesota (November 2009) Guidelines for Rationalizing Motor Energy Consumption (http://www.mntap.umn.edu/greenbusiness/energy/123-MotorTips.htm) accessed May 2006.

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.

to perform the work and the apparent power supplied to the motor represents the power factor. The goal of efficient energy use is to correct the reactive power to get as close as possible to a power factor of one. This correction can be done by extending the line feeding the motor loads.

1. **Limiting power imbalance:** In addition to correcting the power factor, ensuring that the motor is supplied with sufficient power helps increase both its efficiency and lifespan. If necessary, a power controller can be installed on the motor to ensure good control over the amount of incoming electricity.
2. **Motor slip:** This is the difference between the synchronous speed produced by the incoming electricity and the number of poles in the motor winding, and its actual speed. It is measured in frequency units. It is a characteristic of motors that should be considered when purchasing a motor for a specific task. High-efficiency motors have a small slip compared to standard efficiency motors.

   Figure 2-3 Motor Operation and Wasted Energy

Thermostat

Workplace Temperature

These devices are important for controlling the temperature in the building's interior spaces and can significantly affect its electricity consumption. Due to the high temperature and humidity in Abu Dhabi, especially during the summer, air conditioners are usually run throughout the day. The amount of cooling provided by any air conditioner depends on two factors: the thermostat setting and the amount of heat entering the building through windows, doors, and walls (see Section 4 of this guide). The lower the temperature set on the thermostat, the harder the air conditioner will work, thus increasing the amount of energy it consumes. The electricity consumed by an air conditioner can be reduced by 3% for every degree the thermostat is raised. Studies have indicated that setting the thermostat to 24°C can provide the desired balance between user comfort and efficient electricity consumption.

MRB Network website for identifying efficient electric motor consumption. (http://www.mrb78.info/?page_id=14008) accessed July 2016

Electrical Construction & Maintenance: Minimizing AC Induction Motor Slip (http://ecmweb.com/content/minimizing-ac-induction-motor-slip) accessed July 2016

Engineering Toolbox, AC Motor Speed Control [http://www.engineeringtoolbox.com/electrical-motor-slip-d_652.html] accessed July 2016

Consumer Energy Center, Tips (http://www.consumerenergycenter.org/tips/summer.html) accessed June 2016

According to the resolution issued by the Executive Committee No. (45C/01/2016).

Dubai Electricity and Water Authority (August 2011) extended its "Set your AC to 24°C" campaign to the commercial sector (http://e-services.dewa.gov.ae/NewsHist/details.aspx?id=02433114000000000000000002433114) accessed July 2016.

In addition to adjusting the thermostat, determining the time when building conditioning is necessary provides an opportunity to rationalize electricity consumption. To achieve a balance between efficient electricity use and providing maximum comfort for building occupants, it is recommended to install programmable digital thermostats. Depending on the period during which people are in the building, thermostats can be set to adjust their temperature, which includes raising the temperature in empty areas and then returning it to its normal setting a suitable time before people enter the building to provide them with comfort. This process has proven effective in significantly reducing electricity consumption in government buildings and homes compared to setting the device to a single temperature throughout the day. Most thermostats today are equipped with motion sensors, similar to those used in lighting motion sensors, and another feature to read the occupancy level of the space, thus working to reduce the amount of energy consumed in air conditioning by lowering the temperature in empty areas. As a general rule, thermostats should be set to at least 24°C during the summer, keeping in mind that the closer the internal temperature is to the external temperature, the lower the energy consumed.

Building Retro-commissioning

Building Retro-commissioning

This process involves evaluating and adjusting the existing devices, equipment, and systems to make them more energy-efficient, including energy use. This process includes studying buildings that have been previously evaluated, for example, evaluated at the end of the construction process and before use, while the retro-commissioning process includes evaluating buildings that have never been evaluated before or a building where modifications have been made to its original functions and specifications. These programs aim to address all issues that may arise during the building's use and should be done periodically (semi-annually, annually, or at the beginning of each season) depending on the availability of a building maintenance program. The importance of making adjustments is that it determines, in detail, the various operating conditions of all systems used in the building and allows for improvements to be made. The retro-commissioning process consists of four phases: planning, investigation, validation, and building handover.

CANMET Energy (March 2008) Recommissioning Guide for Building Owners and Property Managers, Version 1 (http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/NRCan_RCx_Guide.pdf) accessed May 2016.

Cool Air Distribution Systems

Air Distribution Systems

Air distribution systems distribute cool air to all areas of the building to ensure the required comfort levels for employees and visitors. Therefore, it is essential to maintain and protect these systems to maximize electricity efficiency and reduce its purchase cost. This includes studying many of the previously discussed options or evaluating other devices, such as fans and filters. The electricity distribution system should be maximized before developing the air conditioning system to get the most benefit from the energy saved for the building. If the air distribution system is inefficient, for example, if there is a leak from the pipes or the size of the device itself is inappropriate, even the best air conditioning unit will not work effectively.

Impact of Lighting Systems on Air Conditioning

Lighting and Heating, Ventilation, and Air Conditioning (HVAC) Systems

Lighting and Cooling Works

Lighting directly affects a room's air conditioning needs. When a lamp emits light, it also radiates heat into its surroundings. Inefficient light sources emit more heat into their surroundings for every beam of light they release, which requires greater use of air conditioning to reduce the effect of the heat generated by the lighting process. A previous study conducted in the UAE showed that replacing traditional incandescent light bulbs with more energy-efficient ones leads to a 65% reduction in electricity consumed for lighting and a 7% reduction in electricity consumed for air conditioning[27]. It is preferable to move towards using efficient lighting systems before making any modifications to the air

conditioning systems to ensure maximum benefit from those modifications.

Studying Air Conditioning Systems

Managers of government buildings can conduct a preliminary study to identify the main uses of energy, opportunities to improve its consumption efficiency, and the need for a comprehensive review of the building's electricity needs. The study on air conditioning should include the key points mentioned in this guide. Appendix B provides guidance on the essential aspects that this study should cover, which may not take more than two hours, depending on the size of the systems used in the building. The collected information about the air conditioning systems should then be submitted to the distribution company (Abu Dhabi Distribution Company or Al Ain Distribution Company), which will use this information to determine the possibility of nominating this building for an energy use review, which will then identify some measures to help reduce consumption.

[27] Ecological Footprint Initiative (December 2014). Benefits of effective application of lighting systems in the UAE. (http://d2ouvy59p0dg5k.cloudfront.net/downloads/auh_english_1.pdf) Accessed May 2016.

Lighting Systems

Lighting consumes about 15% of the energy consumed by any office building[28]. Lighting ranks second after air conditioning in electricity consumption in any building, and any measures related to it can lead to a quick and easy reduction in electricity consumption.

Figure 1-3 Description of the process of converting electricity to light in each type of electric lamp[30]

Incandescent bulbs light up by passing electricity through a specific filament until it becomes hot enough to glow. Incandescent bulbs waste 90% of their energy as heat.

In compact fluorescent lamps (CFLs), an electric current flows through a tube containing certain gases. This reaction produces ultraviolet light

which is converted into visible light by the fluorescent coating on the inner surface of the tube.

Light from a light-emitting diode (LED) is produced with high efficiency through the movement of electrons through a semiconductor material towards a small light source. A very small amount of heat is produced and is dissipated within the product itself. In high-quality products, the bulbs are cool to the touch.

The available types of lamps range from traditional incandescent to light-emitting diode (LED) lamps and compact fluorescent lamps (CFLs). Figure 1-3 provides a description of how each of these lamp types produces light from electricity.

Figure 2-3 provides a comparison between the electricity usage and lifespan of each of the three types. Light-emitting diode (LED) lamps and compact fluorescent lamps (CFLs) are the two most widespread types in the world to replace the traditional incandescent lamp. LED lamps are finding increasing acceptance because their lifespan is ten times longer than fluorescent lamps, their operating cost is lower, and recent technologies introduced have made their market price cheaper than before. Despite the many criticisms directed at CFLs for many years due to the presence of mercury, which can lead to environmental degradation, they can be considered a good alternative to traditional incandescent lamps if disposed of properly.

[28] Inhabitat (May 2012). How to Switch Your Bulbs to LEDs to Get Ready for the Incandescent Bulb Phase-Out. Taken 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.

[29] KQED Science (July 2013). Comparing LED, CFL, Incandescent Light Bulbs for Energy Saving. (http://ww2.kqed.org/quest/2013/06/27/comparing-led-cfl-incandescent-light-bulbs-energy-saving) Accessed May 2016.

[30] The British University in Dubai (January 2016). Building Maintenance Strategies and their Impact on Energy Consumption in the United Arab Emirates. (http://content.buid.ac.ae/events/Proceedings/58E16D154.pdf) Accessed July 2016.

Figure 2-3 Comparison between Light Emitting Diode (LED) and Compact Fluorescent Lamps (CFL) in terms of electricity consumption and lifespan[31]

Traditional Incandescent Bulb	Compact Fluorescent Lamp (CFL)	Light Emitting Diode (LED) Lamp
60 Watts	14 Watts	12.5 Watts
Average bulb lifespan ~1200 hours	Average bulb lifespan ~10,000 hours	Average bulb lifespan ~25,000 hours
Average consumption in 20 years: 21 bulbs	Average consumption in 20 years: 2.5 bulbs	Average consumption in 20 years: 1.4 bulbs

UAE Lighting Standards

- Abu Dhabi International Energy Conservation Code 2013
- Lighting Maintenance and Operation
- Energy-Efficient Lighting
- Lighting

The United Arab Emirates has recently approved regulations related to products used for residential lighting that prohibit the use of traditional incandescent bulbs and other products that do not meet specific standards. It also banned the sale of incandescent bulbs in retail stores starting from July 1, 2014, and banned the sale of their fittings starting from January 1, 2015. As a result, the use of traditional bulbs in government buildings is no longer expected.

In addition to inefficient lighting systems, some residents of Abu Dhabi waste electricity by leaving lights on even in unoccupied areas and using oversized lamps that exceed the needs of a specific area in the building. In the following sections, we provide guidance to officials responsible for government buildings on improving the efficiency of lighting use inside buildings without reducing the required level of illumination.

The illuminance level is another important factor to consider when balancing electricity efficiency in lighting and user comfort. In 2013, the Department of Municipal Affairs and Transport launched the "Abu Dhabi

International Energy Conservation Code," which includes recommendations for the required lighting power level for each building in Table 2-5-505 under the name "Interior Lighting Level" found on page 63 of the said code[32].

Lighting fixtures require periodic maintenance, including cleaning and replacing bulbs and their bases. It is necessary to immediately disconnect the lamp fixture when the base exceeds its lifespan and replace the base as soon as possible to save as much electricity as possible.

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

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

Lighting Sources - Individual Offices

Office Lighting Design

Office Lighting Facts

There are several methods that can be applied to improve the use of lighting in individual offices in Abu Dhabi, and these improvements have been directly linked to increasing employee productivity and enhancing the overall environment. According to the 2013 Abu Dhabi Energy Conservation Code, the optimal lighting power for individual offices is 10.8 W/m^2[35]. The lighting level in offices can be improved in several ways, including:

1. Replacing lighting fixtures with more efficient ones.
2. Using natural light through windows during the day instead of artificial lighting.
3. Adjusting the position of lamps in the office, such as installing an overhead lamp or a desk lamp.
4. Ensuring that the lighting level is appropriate.
5. Installing motion sensor lighting controls.
6. Ensuring that lights are turned off after working hours.

As mentioned earlier, most offices in Abu Dhabi are equipped with more lighting than required, leading to higher electricity costs. Modifications can

easily be made to lighting use in open-plan offices, such as resorting to natural sunlight during the day or placing a lamp on each desk, which could significantly reduce electricity bills and increase employee productivity. Enabling each employee to control their own lamp, such as turning it on and off as needed, and adding more light switches can help implement this initiative. Additionally, adjusting the lighting level in each room according to the level of computer screen reflection while considering user comfort is also a very useful measure. The 2013 Abu Dhabi Energy Conservation Code states that the optimal lighting power level is 10.8 W/m^2 for open-plan offices[36]. Table 1-3 provides recommendations for appropriate lighting levels for various office tasks.

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

Table 1-3 Required Illuminance for Various Office Activities[35,36,37,38]

Office Activity	**Illumination Level (Lux)**	**Additional Information**
Computers	500-1000	
Overhead lighting	300-500	If no specialized lighting is available
Reading documents, papers, or newspapers	250-500	
Viewing photos and phone directories	500-1,000	
Performing visual or small-scale tasks for long periods	2,000-5,000	
Performing visual tasks for very long periods	5,000-10,000	
Performing very specific visual tasks with low light reflection and small sizes	10,000-20,000	

Lux is the unit of measurement for illuminance, where 1 Lux = 1 Lumen / square meter, and a Lumen is the unit of measurement for light emitted from any source.

Lighting Sources - Common Areas

We also need to consider the lighting needs for areas shared by many individuals (e.g., meeting rooms and corridors). These areas should only be lit when in use, and the lighting should be dimmable according to the room's needs. The 2013 Abu Dhabi IECC recommends setting the lighting power density to 11.8 W/m2 for a meeting room and 5.4 W/m2 for corridors[39].

[36] Lighting Deluxe: Office Lighting, Best Practices for Designing Office Lighting Systems. (http://www.lightingdeluxe.com/workplace-lighting-ergonomics.html) Accessed May 2016.

[37] Canadian Centre for Occupational Health and Safety, taken from: (http://www.ccohs.ca/oshanswers/ergonomics/office/eye_discomfort.html) Accessed May 2016.

[38] Humanscale: Specialized Lighting Solutions, Their Economic Benefits and Comfort Provision. (http://www.humanscale.com/userfiles/file/tasklightingsolutions.pdf) Accessed May 2016.

[39] The Engineering Toolbox: Illuminance - Recommended Light Levels. (http://www.engineeringtoolbox.com/light-level-rooms_d_708.html) Accessed May 2016.

Lighting Sources - Specialized Uses

Many government buildings in Abu Dhabi have meeting rooms or lecture halls. These are considered "special needs" rooms according to their specific lighting requirements, which differ from the lighting in an entrance or office room. These rooms are usually large, with many seats for a large group of people to attend a conference, video presentation, or similar events. These multi-use rooms have the feature of adjusting lighting through individual use to achieve maximum efficiency (e.g., turning off the lights during a screen presentation). The 2013 Abu Dhabi IECC recommends setting the lighting power density to 6.5 W/m2 for the main conference hall, 11.8 W/m2 for a conference room, and 14.0 W/m2 for a lecture hall.

Motion Sensors

Motion sensors are essential in buildings to control lighting when no one is present. They are equipped with sensors that can detect when a person

enters or leaves a room and can send infrared, ultrasonic, microwave, or other electronic signals that communicate the message via computers to the lighting sources to turn on or off. Installing this type of device is an easy and inexpensive way to control lighting and thus reduce energy consumption in buildings.

Daylight Sensors

Daylight Sensors

Daylight sensors recognize the availability of sunlight in the area surrounding the building and then adjust the artificial lighting fixtures to provide the appropriate amount of light in the space. They are economical and effective in reducing the energy consumed by lighting fixtures, especially in the presence of large windows that allow large amounts of sunlight to enter.

Exterior Lighting

Lighting

Many government buildings have outdoor areas or parking lots that require lighting. Exterior lighting should be controlled in the same way as interior lighting, as explained in the previous sections.

The following points should be taken into account when choosing exterior lighting systems:

1. Lighting power level
2. Types of lamps used, especially those that provide soft white light
3. Lighting controls, especially timers and daylight sensors.

Exterior light sources should be placed only in the areas that need them and at the required and appropriate level.

Studying Lighting Systems

Auditing Tools

Similar to studying air conditioning systems, the facility manager can study and evaluate the lighting systems in the government building. This includes walking around to identify the types of lighting systems used throughout the building. It should be noted that it is not necessary to evaluate every single lamp, but the overall situation of the lighting systems should be assessed.

The following points should be recorded when conducting this study: types of systems used for lighting in offices, corridors, and meeting rooms, the total number of lamps in each area, maintenance and repair systems for lighting, lamp operating hours, and the availability of control systems. Appendix C provides a data collection form for the devices that should be included in this study, which may not take more than two hours depending on the size of the building. The information collected during this study should be submitted to the distribution companies (Abu Dhabi Distribution Company and Al Ain Distribution Company) so they can decide whether to include this building in a comprehensive energy consumption review, through which measures can be developed to help reduce consumption.

Building Envelope

Building Energy

Since the buildings targeted by this guide are existing ones, this section will present the available low-cost options for building insulation. It includes implementing some measures that enable efficient energy consumption regarding building insulation, window modifications, leak treatment, and other issues related to the work environment[40].

1. **Walls:** More insulation systems can be added to exterior walls to reduce the amount of heat entering the building from its surroundings, and materials can be added to prevent hot air leakage through them, such as cracks, to ensure heat does not leak from the outside to the inside.

2. **Windows:** Window curtains can be replaced with heat-reflective ones to limit the leakage of external heat into the building.
3. **Window modifications:** Old window frames can be replaced with non-metallic insulating ones to limit heat leakage from the outside to the inside. Replace single-pane glass windows with double or triple-pane insulating windows. Due to the high temperature in Abu Dhabi, installing thermal insulation film on window glass also helps to limit heat leakage from the outside to the inside.
4. **Exterior doors:** Revolving doors limit the leakage of heat from the inside to the outside and the leakage of conditioned air from the inside to the outside, which helps to increase the efficiency of the air conditioning systems.
5. **AC leakage:** Installing low-quality heat-sealing materials on the walls leads to heat leakage from the inside to the outside.
6. **Roofs:** Heat leakage into the building can be reduced by using heat-reflective materials, such as white stones or reflective paint, on building roofs. Although these materials are not a suitable substitute for roof insulation, such cool roof technology can be applied to existing buildings and has proven successful in reducing heat leakage into the building through the roof.

[40] National Renewable Energy Laboratory, Energy Efficiency in Commercial Buildings, taken from: [http://www.nrel.gov/tech_deployment/pdfs/commercial_building_checklists.pdf] Accessed May 2016.

Miscellaneous Electrical Appliances

Office Equipment

Office Auditing Tools

Many electrical tools and equipment are used in Abu Dhabi's government offices, such as printers, display screens, electronic vending machines, and fax machines. Since these machines consume a lot of energy continuously, even when not in use, and many of these machines are used very sparingly throughout the day, this leads to an unnecessary increase in energy consumption costs and the associated gas emissions. Many of these devices are left running after office hours. However, many new machines are now being manufactured with energy-saving features that can be set

in a few minutes. These allow the machine to switch to a low power consumption mode or standby when not in use, for example, when users are away from their computer screens while eating or printers are idle throughout the workday. The user manual provided with the devices can be consulted to learn about the presence of these features in the equipment used in the office.

Computer server rooms consume a lot of electricity, so better data management and eliminating unused services are simple measures that can help conserve a lot of electricity in such rooms. It is also important to determine the exact number of electrical devices required in any office according to the number of employees working there. The fewest possible number of personal printers, used by a single person, should be used in offices as they are an additional source of electricity consumption. Electrical equipment that is not used continuously should be turned off or shut down and turned on only when needed to conserve the largest possible amount of consumed electricity.

Raising Employee Awareness

It is important to conduct awareness campaigns for office users on improving their use of equipment and the office environment to achieve the most efficient use of electricity. Awareness methods vary from printed materials and brochures to organizing lectures or sending emails that include information about the consumption of electronic devices and the measures to reduce it. For example, employees can be informed of the need to shut down their computers at the end of the workday to reduce electricity waste.

To organize an employee awareness program, the following points should be considered[41]:

1. **Teamwork:** To ensure the success of the electricity efficiency program, the senior management of the institution must commit to its contents and appoint a responsible official and a specialized team to implement it.
2. **Data and Information Collection:** To determine the amount of electricity targeted for reduction, it is necessary to collect information and data on electricity usage in the building and compare it with other buildings.

3. **Setting Goals:** Once the data and information have been collected, the next step is to set the objectives of the awareness campaign, which also includes bringing about a change in employee behavior.
4. **Promotion and Implementation:** The awareness campaign must be promoted through various communication channels and among all employees of the government entity. This program must be implemented through these communication channels and other activities it includes throughout its duration.
5. **Evaluation:** Upon completion of the program, its success must be evaluated. To ensure continuous improvement in the program, the success in implementing each of its set objectives must be verified, and the situation in the building must be compared with other government buildings.

Abu Dhabi Distribution Company and Al Ain Distribution Company will organize meetings with managers of government entities to provide them with some guidance on how to involve employees in reducing electricity consumption in their buildings. These meetings also aim to discuss the contents of this guide, provide guidance on the next steps to be taken to conduct a detailed study on the status of cooling and lighting systems, clarify the challenges facing facility managers of government entities in the Emirate of Abu Dhabi, and answer all questions and inquiries they may have. Guidance on how to raise employee awareness and how to promote these campaigns will also be provided during the meeting, with the aim of helping all government institutions achieve their set goals for reducing their electricity consumption according to the established schedule.

[41] Natural Resources Canada. Implementing a Program to Raise Awareness of the Importance of Efficient Energy Consumption. (https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/files/pdf/publications/commercial/Awareness_Program_e.pdf) Accessed July 2016.

Appendix A: Maintenance and Repair Protocols for Air Conditioning Systems

Appendices A-1 through A-6 provide the following protocols for the maintenance and repair of air conditioning units:

1. **Appendix A-1:** Maintenance and repair protocols for central chillers and district cooling systems.

2. **Appendix A-2:** Maintenance and repair protocols for split air conditioners.
3. **Appendix A-3:** Maintenance and repair protocols for mini-split air conditioners.
4. **Appendix A-4:** Maintenance and repair protocols for ducted split air conditioners.
5. **Appendix A-5:** Maintenance and repair protocols for packaged air conditioners.
6. **Appendix A-6:** Maintenance and repair protocols for window air conditioners.

Appendix A-1: Maintenance and Repair Protocols for Central Chillers and District Cooling Systems.

- Check the refrigerant level and add more if it is low in each water chiller.
- Check all parts of the connecting pipes and valves to ensure there are no refrigerant leaks.
- Check the insulation of the refrigerant distribution pipes and repair any damaged parts.
- Check the chilled water control valve.
- Check the oil level in the oil compressor after running the water chiller at maximum capacity for at least 15 minutes, repair any leaks, and ensure the oil is at the required level.
- Check the electrical connections of the oil compressor to ensure they are tightly secured, check the wires for soundness and quality of insulation, and replace any damaged parts.
- Check the heater element.
- Measure the suction and discharge pressure of the air conditioner and compare it with the manufacturer's specifications.
- Ensure that an electrical connection point is located near the air conditioning unit.
- Check the electrical supply line, clean and tighten any loose parts, and replace it if the insulation is faulty.
- Check the accuracy of the thermostat. If there is a difference of more than 1.2°C from its set point, replace it.
- Ensure that the cold water distribution network is properly treated.
- Ensure there is no pressure drop across the refrigerant filter dryers and replace any damaged ones.

- Check and clean the chilled water controls.
- Ensure there are no obstructions to the airflow to the condenser, then remove any moving parts to a distance of at least 60 cm as much as possible.
- Straighten the condenser cooling fan fins. If they are severely damaged, replace the condenser.
- Clean the condenser fins. If they are very dirty, use a brush, compressed air, or a cleaning liquid, then wipe them with water.
- Ensure there are no cracks on the condenser fan blades, replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft is running smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace any damaged ones.
- Check the fan belt and replace it if it is damaged. Ensure it is tightly secured.
- Check and clean the cooler and ensure it is not damaged or dirty.
- The condenser must be cleaned as follows:
  - The chillers must be turned off and left for at least one hour before starting to clean the condenser coils.
  - First, clean the chillers of dust and fibers using a soft, non-metallic fiber brush.
  - The condenser coils must be cleaned from the inside out using an environmentally friendly cleaner as described below.
  - The condenser coil cleaner must be non-flammable, non-bacterial, non-allergenic, biodegradable, and 100% environmentally friendly so as not to cause any damage to the condenser coils or surrounding equipment such as electrical connections or metal surfaces.

Appendix A-2: Maintenance and Repair Protocols for Split Air Conditioners

Outdoor Unit

- Check the outer casing for any rust or damage. Note that if the outer casing is damaged, it may affect the unit's performance.
- Ensure the unit is securely mounted on the roof and does not move when the compressor is running.

- Ensure the electrical connection point is close to the unit.
- Check the electrical connections to ensure they are clean and securely fastened. Replace them if the insulation is damaged.
- Ensure there are no obstructions to the airflow to the condenser, then remove any moving parts to a distance of at least 60 cm as much as possible.
- Straighten the condenser cooling fan fins. If they are severely damaged, replace the condenser.
- Clean the condenser fins. If they are very dirty, use a brush, compressed air, or a cleaning liquid, then wipe them with water.
- Ensure there are no cracks on the condenser fan blades, replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft is running smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace any damaged ones.
- Check the fan belt and replace it if it is damaged. Ensure it is tightly secured.
- Check and clean the cooler and ensure it is not damaged or dirty.

Indoor Unit

- Check the heat exchangers, air handling units, or fan coil units.
- Clean and repair the evaporator coil fans, if necessary.
- Ensure there is no object obstructing ventilation.
- Check the blower, repair it if necessary, and clean it.
- Lubricate the blower motor.
- Check the electrical connections and repair any damaged ones.
- Clean the air filters and replace any damaged parts.
- Clean the condensate drain parts and ensure they are working properly.
- Check the parts near the air duct and seal any openings that could lead to cold air leakage.
- Check all thermostats and set the indicator to 24°C.

Operation, Maintenance, and Repair

- Turn on the air conditioner first and let it run for at least 10 minutes until the temperature and pressure stabilize.

- Ensure the thermostat is working and adjusted correctly. Repair or replace any damaged parts.
- Ensure there is good ventilation from the air conditioner.
- Measure and record the inlet and outlet temperatures of the air conditioning system.
- Check the evaporator motor mounts and replace any damaged ones.
- Check the condenser fan motor mounts and replace any damaged ones.
- Check and repair the compressor mounts.
- Record the incoming electrical frequency to the compressor and compare it with the manufacturer's specifications.
- Check the refrigerant line for any leaks using soapy water, electronic leak detectors, or other suitable means, then repair the faults causing the leak.
- After repairing the leak, check the refrigerant charge by any suitable method and add refrigerant if the amount is low. If the amount of gas is more than required, place the excess in a tightly sealed container so it does not leak into the surrounding environment.
- If the refrigerant system is opened, for example, due to replacing the compressor, install new filter-driers and ensure there are no leaks at the connection point between the strainer and the drier after installation.

Appendix A-3: Maintenance and Repair Protocols for Mini-Split Air Conditioners

Outdoor Unit

- Check the outer casing for any rust or damage. Note that if the outer casing is damaged, it may affect the unit's performance.
- Ensure the unit is securely mounted on the roof and does not move when the compressor is running.
- Ensure the electrical plug is close to the unit.
- Check the electrical connections to ensure they are clean and securely fastened. Replace them if the insulation is damaged.
- Ensure there are no obstructions to the airflow to the condenser, then remove any moving parts to a distance of at least 60 cm as much as possible.
- Straighten the condenser cooling fan fins. If they are severely damaged, replace the condenser.

- Clean the condenser fins. If they are very dirty, use a brush, compressed air, or a cleaning liquid, then wipe them with water.
- Ensure there are no cracks on the condenser fan blades, replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft is running smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace any damaged ones.
- Check the fan belt and replace it if it is damaged. Ensure it is tightly secured.
- Check and clean the cooler and ensure it is not damaged or dirty.

Indoor Unit

- Check the heat exchangers, air handling units, or fan coil units.
- Clean and repair the evaporator coil fans, if necessary.
- Ensure there is no object obstructing ventilation.
- Check the blower, repair it if necessary, and clean it.
- Lubricate the blower motor.
- Check the electrical connections and repair any damaged ones.
- Clean the air filters and replace any damaged parts.
- Clean the condensate drain parts and ensure they are working properly.
- Check the parts near the air duct and seal any openings that could lead to cold air leakage.
- Check all thermostats and set the indicator to 24°C.

Operation, Maintenance, and Repair

- Turn on the air conditioner first and let it run for at least 10 minutes until the temperature and pressure stabilize.
- Ensure the thermostat is working and adjusted correctly. Repair or replace any damaged parts.
- Ensure there is good ventilation from the air conditioner.
- Measure and record the inlet and outlet temperatures of the air conditioning system.
- Check the evaporator motor mounts and replace any damaged ones.
- Check the condenser fan motor mounts and replace any damaged ones.
- Check and repair the compressor mounts.

- Record the incoming electrical frequency to the compressor and compare it with the manufacturer's specifications.
- Check the refrigerant line for any leaks using soapy water, electronic leak detectors, or other suitable means, then repair the faults causing the leak.
- After repairing the leak, check the refrigerant charge by any suitable method and add refrigerant if the amount is low. If the amount of gas is more than required, place the excess in a tightly sealed container so it does not leak into the surrounding environment.
- If the refrigerant system is opened, for example, due to replacing the compressor, install new filter-driers and ensure there are no leaks at the connection point between the strainer and the drier after installation.

Appendix A-4: Maintenance and Repair Protocols for Ducted Split Air Conditioners

Outdoor Unit

- Check the outer casing for any rust or damage. Note that if the outer casing is damaged, it may affect the unit's performance.
- Ensure the unit is securely mounted and does not move when the compressor is running.
- Ensure the electrical plug is close to the unit.
- Check the electrical connections to ensure they are clean and securely fastened. Replace them if the insulation is damaged.
- Ensure there are no obstructions to the airflow to the condenser, then remove any moving parts to a distance of at least 60 cm as much as possible.
- Straighten the condenser cooling fan fins. If they are severely damaged, replace the condenser.
- Clean the condenser fins. If they are very dirty, use a brush, compressed air, or a cleaning liquid, then wipe them with water.
- Ensure there are no cracks on the condenser fan blades, replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft is running smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace any damaged ones.

- Check the fan belt and replace it if it is damaged. Ensure it is tightly secured.
- Check and clean the cooler and ensure it is not damaged or dirty.

Indoor Unit

- Check the heat exchangers, air handling units, or fan coil units.
- Clean and repair the evaporator coil fans, if necessary.
- Ensure there is no object obstructing ventilation.
- Check the blower, repair it if necessary, and clean it.
- Lubricate the blower motor.
- Check the electrical connections and repair any damaged ones.
- Clean the air filters and replace any damaged parts.
- Clean the condensate drain parts and ensure they are working properly.
- Check the parts near the air duct and seal any openings that could lead to cold air leakage.
- Check all thermostats and set the indicator to 24°C.

Operation, Maintenance, and Repair

- Turn on the air conditioner first and let it run for at least 10 minutes until the temperature and pressure stabilize.
- Ensure the thermostat is working and adjusted correctly. Repair or replace any damaged parts.
- Ensure there is good ventilation from the air conditioner.
- Measure and record the inlet and outlet temperatures of the air conditioning system.
- Check the evaporator motor mounts and replace any damaged ones.
- Check the condenser fan motor mounts and replace any damaged ones.
- Check and repair the compressor mounts.
- Record the incoming electrical frequency to the compressor and compare it with the manufacturer's specifications.
- Check the refrigerant line for any leaks using soapy water, electronic leak detectors, or other suitable means, then repair the faults causing the leak.
- After repairing the leak, check the refrigerant charge by any suitable method and add refrigerant if the amount is low. If the amount of gas is

more than required, place the excess in a tightly sealed container so it does not leak into the surrounding environment.
- If the refrigerant system is opened, for example, due to replacing the compressor, install new filter-driers and ensure there are no leaks at the connection point between the strainer and the drier after installation.

Appendix A-5: Maintenance and Repair Protocols for Packaged Air Conditioners

Cooling/Condensing Unit

- Check the outer casing for any rust or damage. Note that if the outer casing is damaged, it may affect the unit's performance.
- Ensure the unit is securely mounted and does not move when the compressor is running.
- Ensure the electrical plug is close to the unit.
- Check the electrical connections to ensure they are clean and securely fastened. Replace them if the insulation is damaged.
- Ensure there are no obstructions to the airflow to the condenser, then remove any moving parts to a distance of at least 60 cm as much as possible.
- Straighten the condenser cooling fan fins. If they are severely damaged, replace the condenser.
- Clean the condenser fins. If they are very dirty, use a brush, compressed air, or a cleaning liquid, then wipe them with water.
- Ensure there are no cracks on the condenser fan blades, replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft is running smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace any damaged ones.
- Check the fan belt and replace it if it is damaged. Ensure it is tightly secured.
- Check and clean the cooler and ensure it is not damaged or dirty.

Ventilation/Evaporation Unit

- Check the heat exchangers, air handling units, or fan coil units.

- Clean and repair the evaporator coil fans, if necessary.
- Ensure there is no object obstructing ventilation.
- Check the blower, repair it if necessary, and clean it.
- Lubricate the blower motor.
- Check the electrical connections and repair any damaged ones.
- Clean the air filters and replace any damaged parts.
- Clean the condensate drain parts and ensure they are working properly.
- Check the parts near the air duct and seal any openings that could lead to cold air leakage.
- Check all thermostats and set the indicator to 24°C.

Electricity Consumption Rationalization Guide for Government Entities

Operation, Maintenance, and Repair:

- Turn on the air conditioner first and let it run for at least 10 minutes until the temperature and pressure stabilize.
- Ensure the thermostat is working and set correctly, and repair or replace any damaged parts.
- Make sure the ventilation from the air conditioner is good.
- Measure and record the inlet and outlet temperatures of the air conditioning system.
- Inspect the evaporator motor mounting parts and replace any damaged ones.
- Inspect the condenser fan motor mounting parts and replace any damaged ones.
- Inspect and repair the compressor mounting parts.
- Record the incoming electrical frequency to the compressor and compare it with the manufacturer's specifications.
- Check the refrigerant line for any leaks using soapy water, electronic leak detectors, or other suitable means, then repair any faults causing leaks.
- After repairing the leak, check the refrigerant charging system using a suitable method and add refrigerant if the amount is low. If the amount of gas is more than required, place the excess in a sealed container to prevent it from leaking into the surrounding environment.

- If the refrigerant system is open, for example, due to replacing the compressor, install new filter-driers and ensure there are no leaks at the connection point between the filter and the drier after installation.

Appendix 6: Maintenance and Repair Protocols for Window Air Conditioners

Cooling / Condensing Unit

- Inspect the outer casing for any rust or damage. Note that if the outer casing is damaged, it may affect the unit's performance.
- Ensure the unit is securely mounted and does not move when the compressor is running.
- Make sure the electrical outlet is close to the unit.
- Inspect the electrical connections to ensure they are clean and tight. Replace them if the insulation is damaged.
- Ensure there are no obstructions to the airflow to the condenser, then clear any objects within a distance of at least 60 cm if possible.
- Straighten the condenser cooling fan blades. If they are severely damaged, replace the condenser.
- Clean the condenser fan blades. If they are very dirty, use a brush, compressed air, or a cleaning solution, then rinse with water.
- Check the condenser fan blades for any cracks. Replace them or straighten them. If they are dirty, clean them.
- Ensure the motor shaft operates smoothly and without any obstructions.
- Ensure the motor's electrical connections are in good condition. Clean and tighten any loose parts and replace damaged ones.
- Inspect the fan belt and replace it if it is damaged. Ensure it is properly tightened.
- Inspect and clean the cooler, ensuring it is not damaged or dirty.

Ventilation / Evaporator Unit

- Inspect the heat exchangers, air handling units, or fan coil units.
- Clean and repair the evaporator coil fans, if necessary.
- Ensure that no object is obstructing the ventilation.
- Inspect the air blower, repair it if necessary, and clean it.

- Lubricate the blower motor.
- Inspect the electrical connections and repair any damaged ones.
- Clean the air filters and replace any damaged parts.
- Clean the drain line and ensure it is working properly.
- Inspect the areas near the air duct and seal any openings that could lead to cold air leakage.
- Check all thermostats and set the indicator to 24 degrees Celsius.

Appendix (B): Cooling Systems Survey Form

1. Type of Cooling Unit (Check the appropriate box)

☐ Zoned central air conditioning system
☐ Central chiller system
☐ Split air conditioning units system
☐ Packaged air conditioning units system
☐ Mini-split air conditioning units system
☐ Ducted split air conditioning units system
☐ Window air conditioners

2. Cooling Unit Capacity

Ton _____

or

kWh _____

3. Air Conditioning System Efficiency Rating

Watt _____ Coefficient of Performance (COP): _____

or

BTU/Wh _____ Energy Efficiency Ratio (EER): _____

4. Type of Refrigerant (Check the appropriate box)

☐ R-22
☐ R-134
☐ R-134a
☐ R-141b

☐ R-12
☐ R-123
☐ R-245fa
☐ R-407C
☐ R-417A
Other types: _____

5. Age of Air Conditioning Unit (Check the appropriate box)

☐ More than one year
☐ From one to five years
☐ From five to ten years
☐ From ten to twenty years
☐ Less than twenty years

6. General Condition of the Outdoor AC Unit (Compressor, pump, and other parts) (Check the appropriate box)

☐ Good condition = No visible leaks, all parts are working well, and the unit is clean
☐ Fair condition = There is a minor leak, not all parts are working at full capacity, maintenance is not regular, and the unit is somewhat dirty
☐ Poor condition = There are many major leaks, the unit has not been well-maintained, it is very dirty, all parts are not working well, and the entire AC system should be replaced

7. Is this air conditioning unit equipped with an automatic Building Management System (BMS), which is a centralized digital system to control temperature, airflow, and operating times, or is it equipped only with a thermostat?

☐ Electronic Building Management System
☐ Thermostat only

Fill out one form per unit

Appendix (C): Lighting Systems Survey Form

Please note that there is no need to study individual units within the room. This survey aims to identify the status of lighting systems in each building. For example, if all offices in the building are similar, one office should be surveyed at this stage, and then the total number of offices should be recorded. If the office is lit by one type of lamp, only one lamp should be described, and the total number of lamps in each office should be mentioned.

1. Room Type

☐ Office
☐ Public gathering area
☐ Corridor
☐ Meeting room
Other _____

2. Room Size

_____ meter X _____ meter

3. Type of Fluorescent Lamps Used (Skip to the next question if there are no fluorescent lamps)

☐ Fluorescent tube
☐ T-12
☐ T-8
☐ T-5

4. Specifications of Fluorescent Lamps Used

Size: _____ cm

Distance between each lamp (lengthwise): _____ cm

Distance between each lamp (widthwise): _____ cm

5. Type of Ballast Used in Each Fluorescent Lamp (if known)

☐ Electronic

☐ Magnetic

6. Other Types of Lamps

Lamp Type	Quantity	Power Consumption in Watts
☐ Traditional Incandescent		
☐ Compact Fluorescent Lamps (CFL)		
☐ High-Intensity Discharge (HID) Lamps - Mercury		
☐ High-Intensity Discharge (HID) Lamps - Sodium		
☐ High-Intensity Discharge (HID) Lamps - Halogen		
☐ Light Emitting Diode (LED) lighting systems		
☐ Other types		

7. Type of Light Fixture

☐ Recessed in wall or ceiling
☐ Surface-mounted on ceiling
☐ Surface-mounted on wall
☐ Other types

8. Is the room equipped with a motion sensor?

☐ Yes
☐ No
Recessed in wall or ceiling

Fill out one form for each room type

Appendix (D): References

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