Supplementary Materials S2
Summary of Energy Conservation Measures (ECMs) and Water Conservation Measures (WCMs)

1- Lighting Automation & Control (Code: LT).

ECM Details	Drawbacks of current System	Proposed Solution	Energy savings
• Lighting is operational irrespective of occupancy at the ablution and ladies' prayer hall. • Outdoor lighting is operated differently at different mosques based on the decision of the caretaker. • Some outdoor lighting is operated based on the prayer timing, but others are kept ON through the night.	• Ineffective use of lamps. • Increased energy consumption. • Increased lamp run hours leading to faster lamp replacement intervals.	Problem 1: Outdoor lighting is used on an average 7hrs Solution 1: Outdoor lighting is divided into two categories, one being essential lighting and other occupancy lighting. Essential lighting will be powered ON based only on the daylight sensor whereas the occupancy lighting will be operated based on an AND gate logic with daylight sensor and lighting timer. Savings: 2 hours per day. Problem 2: Ablution lighting is used on an average 8hrs a day. Solution 2: Incorporating occupancy sensors or vacancy sensors will help in effective reduction of operating hours. It is observed that the Ablution area is used 15-30mins before every prayer and during the cleaning time. Savings: 3 hours per day. Problem 3: Prayer Hall lighting is used on an average 8hrs a day. Solution 3: Operating prayer hall lighting based on prayer timing and occupancy could reduce the average running hours for lamps.	20–35%

2- Energy Efficient Air Conditioning Units (Code: EEACU).

ECM Details	Drawbacks of current System	Proposed Solution	Details of proposed solution	Energy savings
• Some of the HVAC units in the mosques to be extremely old and thus have lost their Cooling efficiency. • Replacement of these units will aid in leveraging the latest technology to bring energy savings.	• Ineffective cooling • Increased compressor ON time. • Higher maintenance or operational costs. • Lower Occupant comfort.	• Inverter Split with Occupancy sensor units as a replacement for Window units and inefficient split units based on ROI calculations for each mosque. • Inverter ducted Split units as a replacement for existing inefficient ducted split units based on ROI calculations for each mosque. • R-401a based Package units as a replacement for existing inefficient package units based on ROI calculations for each mosque.	• Inverter Split with Occupancy Sensor. • Ducted Split with Inverter. • R410a based Package units <u>Non-Inverter AC:</u> In a non-inverter air conditioner, there is no way of controlling the compressor. It operates either at full capacity or none at all. When high amounts of refrigerant are needed it turns on, while the need is low, it turns off, causing unnecessary energy consumption. <u>Inverter AC:</u> When cooling capacity is needed to be increased, the compressor works at a high speed that increases the quantity of refrigerant. On the other hand, when normal temperature is modest, the compressor operates at a low speed and reduces the amount of refrigerant.	30–40%

3- Energy Savers for AC Units (Code: HVACA).

ECM Details	Details of proposed solution	Advantages of the energy saving units	Energy savings
• Installing intelligent energy saving units for old Air conditioning units helps in reducing the energy consumption. • The system detects the compressor load and helps in preventing the cooling coils from freezing. • The system manages an effective ON & OFF cycle to lower the compressor ON time and increase the efficiency of the AC unit.	• Running the air conditioner continuously until the room thermostat turns it off means that the system operates sub-optimally. • The Energy Saver uses a sensor driven software algorithm to determine overcooling of the evaporator and optimize the compressor run time accordingly. • The Solution is effective for units with higher operating hours. • Reducing operating hours of the unit by scheduling will lower the savings due to energy saver units.	• Enhances the life of the compressor. • Helps in preventing icing of the compressor. • Lower Energy consumption of the AC unit.	4.5–10%

4- Variable Refrigerant Volume for HVAC (Code: HVAC).

ECM Details	Details of proposed solution	Advantages of the VRV System	Possible Drawbacks	Energy savings
• VRV System provides a variable refrigerant temperature control for energy saving in partial load condition. • The capacity is controlled by the inverter compressor and variation of the evaporating and condensing temperature of the refrigerant in order to achieve the highest seasonal efficiency.	• VRVs are typically installed with an Air conditioner inverter which adds a DC inverter to the compressor in order to support variable motor speed and thus variable refrigerant flow rather than simply perform on/off operation. • By operating at varying speeds, VRV units work only at the needed rate allowing for substantial energy savings at partial-load conditions.	• Variable refrigerant temperature and low start-up current. • DC fan motor for higher efficiency. • Possibility to connect to Mini BMS for integrated control and monitoring. • High Energy Efficiency. • Precise temperature control. • Zoned Comfort	• Price per ton is extremely high. • Complexity if tonnage to be increased.	25–40%

5- Honeywell Mosque Thermostat for Package U (Code: MSQTHR).

ECM Details	Details of proposed solution	Advantages of the Mosque Thermostat	Energy savings
• Honeywell's Mosque thermostat with Auto-Azan feature detects prayer times according to the mosque's latitude and longitude location, and can help automatically lower temperatures during crowded peak times, while saving energy when the building is unoccupied.	• Compressor ON time can be reduced from 8hrs/day to 5hrs/day. • Higher set points configuration at the thermostats will bring in additional savings. The keypad lock functionality will prevent unauthorized personal from changing the set points or schedule.	• Synchronize with prayer times using Auto-Azan feature according to the mosque location; there is no need for manual adjustment. • Smart holiday and override functions allow flexibility for special occasions. • Keypad lockout to prevent unauthorized changes. • Lower Energy consumption of the AC units.	20–35%

6- IoT Based Infrared Control for Split Units (Code: IBSC).

ECM Details	Details of proposed solution	Advantages of Cielo	Energy savings
• Cielo is a smart IoT device that works on infrared to control the AC units. • The communication is taken over the internet for remote monitoring and control.	• System can perform according to schedule and send remote notifications over the internet. • Average set point can be maintained at 23C and operating hours can reach up to 3.5hrs a day. • The operating hours of the unit can be better managed and controlled remotely. • Higher set points configuration at the thermostats will bring in additional savings. • The keypad lock functionality will prevent unauthorized personal from changing the set points or schedule.	• Remote Control and Monitoring. • Remote Scheduling. • Energy Usage Trends. • Operating hours data. • Override notifications if the operator changes the set points. • Efficient use of AC units thus lowering the energy costs.	10–20%

7- Energy Efficient Lighting Retrofit (Code: LR).

ECM Details	Drawbacks of the current system	Advantages of LED Lighting	Energy savings
• Most of the mosques to contain either halogen or compact fluorescent as their key lighting source.	• Lower Lumens/ Watt. • Leaky bulbs (common with fluorescents), where outside gasses seep inside and disrupt the balance of inert gasses. • Higher lamp replacement intervals resulting in higher operational expenditure.	• Energy Efficiency: Up to 120 lumen/watt and improving. • Durability: Heavy-duty – has no electrode or filament. • Lumen Depreciation: 30% loss at rated life. • Moderate upfront cost	30–50%

8- Water Recycling (Code: WR).

WCM Details	Possible Drawbacks	Advantages of the technology	Possible Drawbacks	Energy savings
• Ablution water consumption is considered to 40% of the total consumption. • Water recycling will help in using the recycled water for toilets and gardening. • A combination of demand side reduction with aerators and discharge side reduction with water recycling will bring significant water saving.	• High upfront cost. • Longer ROI compared to simple aerator installation.	• Saves portable water. • Reduce sever generation. • Up to 30% water cost reduction. • Treated water might be better for gardening as it contains some plant nutrients.	• High upfront cost. • Requires regulatory approval and documentation. • Not suitable for facilities with low occupancy and low water consumption. • Longer ROI compared to simple aerator installation.	15–30%

9- Self-Closing Faucets (Code: SCFWA).

WCM Details	Possible Drawbacks	Advantages of the technology	Possible Drawbacks	Energy savings
• The Self Closing taps helps in avoiding instances of people leaving the taps running or not closing completely.	• High upfront cost. • Longer ROI compared to simple aerator installation.	• Up to 50% water saving. • Easy to Use. • Adjustable flow rates. • No-touch self-closing operation.	• High upfront cost. • Longer ROI compared to simple aerator installation.	30–50%

10- Aerators for Faucets (Code: A).

WCM Details	Details of proposed solution	Advantages of the technology	Energy savings
• Water efficient aerators help in reducing the flow rates of water while keeping the pressure undisturbed. • They are an effective solution to save water at existing faucets	• Flow rates at Ablution Mixers, Wash Basin Mixers and toilet seat mixers can be significantly reduced upon installing the aerators. • Mosques that do not have any water saving aerators or self-closing taps installed can implement this technology.	• Reduce flow rates up to 80%. • Efficient use of water. • Vandal Proof fixtures. • Pressure independent technology for better user experience.	25–80%