SAN DIEGO RCx
IMPROVING BUILDING PERFORMANCE THROUGH RETROCOMISSIONING

		uipment Scheduling and Enabling: No demand savings unless new schedule turns off equipment ing building peak demand period. kWh savings are proportional to the pre- and post-measure operation hours.			**Economizer/Outside Air Loads**: Properly operating economizers will reduce de temperature if the baseline economizer is introducing excessive outside air into the build reduce demand and energy consumption under low ambient conditions.
		Finding Type 1	**Finding Type 2**	**Finding Type 3**	**Finding Type 4**
Finding Type		**Time of Day enabling is excessive**	**Equipment is enabled regardless of need, or such enabling is excessive**	**Lighting is on more hours than necessary.**	**Economizer Operation – Inadequate Free Cooling (Damper failed in minimum or closed position, economizer setpoints not optimized, Night Purge not enabled)**
Finding the Problem	**Problem Identification Method(s):**	Observations of existing schedule and/or printed controls logic. Observation of HOA switch in hand position. Improper time/date settings in controls.	Observations that optimum start/stop does not exist in controls logic, or is not properly implemented. Observation of HOA switch in hand position. Trends show that multiple chillers operate at low load. Improper lat/long settings in controls.	Observations of existing schedule and/or printed controls logic. Trends of equipment current or status show that lights are on more than needed. Evidence of overridden automated lighting controls.	Observation of integrity of components and sensors Functional tests to observe actuation of dampers Trending to observe dynamic performance and coil load.
ata Guidelines	**Preferred Method:**	Trend command signal and power / current during all operating modes (e.g., occupied and unoccupied operation).	Trend command signal and power / current along with any independent variables (e.g., outside air temperature) during all operating modes (e.g., occupied and unoccupied operation).	Trend command signal and power / current during representative day types.	Trend supply air temperature (SAT), mixed air temperature (MAT), outside air temperature (OAT), return air temperature (RAT), economizer damper command, and call for cooling. For Night Purge measures, trend outside air temperature, space temperature, supply fan status and the following (if available): * outside and return air damper position * building mass temperature * chiller power

SAN DIEGO RCx IMPROVING BUILDING PERFORMANCE THROUGH RETROCOMISSIONING		·mand and energy consumption during periods of high ambient ·ling. If the baseline economizer is closed, fixing the economizer will	**Controls Problems:** Eliminating simultaneous heating and cooling reduces both the electricity required for heating, as well as the cooling required to offset the heat. Calculation methods for sensor/thermostat calibration and hunting and loop tuning are not easily generalized due to the wide range of potential failure modes.			**Controls (Setpoint Changes):** Optimizing setpoints can and can also reduce reheat requirements if excessive air is provi	
		Finding Type 5	**Finding Type 6**	**Finding Type 7**	**Finding Type 8**	**Finding Type 9**	**Finding Type 10**
Finding Type		**Over-Ventilation – Outside air damper failed in an open position. Minimum outside air fraction not set to design specifications or occupancy.**	**Simultaneous Heating and Cooling is present and excessive**	**Sensor/Thermostat needs calibration, relocation/shielding, and/or replacement**	**Controls "hunt" and/or need Loop Tuning or separation of heating/cooling setpoints**	**Zone setpoint setup/setback are not implemented or are sub-optimal.**	**Fan Speed Doesn't Vary Sufficiently**
Finding the Problem	**Problem Identification Method(s):**	Observation of integrity of components and sensors Functional tests to observe actuation of dampers Spot measurement of airflow. Trending to observe dynamic performance and coil load.	Trending to identify the extent of this problem. For cold supply temperatures and/or high minimum VAV flow setpoints, see Finding Types 15 and 12, respectively. For leaking valves (whether through a physical, actuation, or control range problem), trend the air temperature difference across the coil or use functional test to determine leakage. All sensors must be calibrated relative to each other so that the temperature difference attributed to leaking valve is not a result of sensor error.	Compare sensor / thermostat readings to an independent calibrated standard (e.g., NOAA real-time weather data).	Observation of existing control feedback loop strategies. Trend loop setpoint versus control feedback data inputs and affected equipment power / current and status.	Observe zone temperature set points during each occupancy period, and optimum start/stop schedule.	Observe fan speeds during system operation. Note relevant system performance (e.g., duct static pressure, space static pressure, positions of VAV box dampers). Temporarily adjust variable (e.g., lower duct static pressure setpoint), observe system performance (e.g. confirm that boxes will not be starved).
ata Guidelines	**Preferred Method:**	Trend mixed air temperature (MAT), outside air temperature (OAT), return air temperature (RAT), economizer damper position, and any related independent variables (e.g., CO2 level).	For electric heat, trend reheat power / current. For gas / hot water heat, trend hot water coil differential temperature. For both, trend call for cooling. For pre-heat, trend air temperature before the preheat coil, after the preheat coil, and after the cooling coil. For leaking valves, trend air temperatures on both sides of the coil.	Trend sensor reading and independent calibrated reading of same parameter.	Trend loop set-point, control feedback data inputs, and affected equipment power / current.	Trend zone temperature set points. Obtain and document zone temperature set point deadband.	Trend relevant points (e.g., static pressure, static pressure setpoint, VAV box positions), and fan power / current. Submit results of any temporary overrides performed as part of system testing.

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		Finding Type 11	**Finding Type 12**	**Finding Type 13**	**Finding Type 14**	**Finding Type 15**	**Finding Type 16**	**Finding Type 17**
Finding Type		**Pump Speed Doesn't Vary Sufficiently**	**VAV Box Minimum Flow Setpoint is higher than necessary**	**HW Supply Temperature Reset is not implemented or is sub-optimal**	**CHW Supply Temperature Reset is not implemented or is sub-optimal**	**Supply Air Temperature Reset is not implemented or is sub-optimal**	**Condenser Water Temperature Reset is not implemented or is sub-optimal**	**Daylighting Control needs optimization**
Finding the Problem	**Problem Identification Method(s):**	Observe pump speeds during system operation. Note relevant system performance (e.g., differential pressure, positions of valves). Temporarily adjust variables (e.g., differential pressure setpoint), observe system performance (e.g., confirm that valves will not be starved).	Observation of VAV box minimum airflow setpoints. Observation of excessive reheat. CO2 spot measurements.	Observations and spot measurements of heating water supply and return temperatures.	Observations and spot measurements of chilled water supply and return temps.	Observations that interior loads do not dominate heating and cooling needs year round and that reset does not exist or is not optimized.	Observations and spot measurements of condenser water supply and return temps.	Observations of existing daylighting system operation and/or printed controls logic.
ata Guidelines	**Preferred Method:**	Trend relevant points (e.g., differential pressure, differential pressure setpoint), and pump power / current. Submit results of any temporary overrides performed as part of system testing. For chiller plants with low ΔT, trend the primary and secondary pump flow, if available, or current and kW. Also trend primary and secondary supply and return temperatures.	Trend reheat power / current, valve position, or hot deck air flow, VAV terminal box airflow, and fan system performance. Spot measure CO2 levels in zones during non-economizer operation. Document observations.	Trend heating water supply and return temperatures and temperature setpoints, and whatever parameter the reset is or will be based upon (such as outside air temperature and/or heating water valve positions). Also perform functional testing if independent variables at the time of trending don't cover the range covered by the reset.	Trend chilled water supply and return temperatures and temperature setpoints, and whatever parameter the reset is or will be based upon (e.g., OAT, valve positions). Also perform functional testing if independent variables at the time of trending don't cover the range covered by the reset.	Trend supply air temperature and temperature setpoint, and whatever parameter the reset is or will be based upon (e.g., OAT, space temperature offset). Also perform functional testing if independent variables at the time of trending don't cover the range covered by the reset.	Trend condenser water supply temperature and temperature setpoint, and whatever parameter the reset is based upon (e.g., outside air wet bulb temperature). Also perform functional testing if independent variables at the time of trending don't cover the range covered by the reset.	Trend lighting status, power / current, occupancy, and lighting levels in each space.

		...vements / Load Reduction: Pre- and post-retrofit schedules remain ...is the difference between the new and old equipment demand, unless the ...eak demand period. kWh savings are proportional to the pre- and post-		**Variable Frequency Drives (VFD):** Variable Frequency Drives allow pumps and fans to operate at lower speeds. This is generally a more energy efficient method to control capacity than using vanes on fans, or discharge or 3-way valves on pumps.	
		Finding Type 18	**Finding Type 19**	**Finding Type 20**	**Finding Type 21**
Finding Type		**Pump Discharge Throttled**	**Over-Pumping**	**VFD Retrofit - Fans**	**VFD Retrofit - Pumps**
Finding the Problem	**Problem Identification Method(s):**	Observations of valve position at pump discharge.	Observation of pump mismatched to equipment served, or observation of low ΔT across a chiller or in a piping loop serving heat transfer equipment.	Fan serves variable flow system, but does not have a VFD.	Pump serves variable flow system, but does not have a VFD. Observation that there is an opportunity to change 3-way valves to 2-way valves. Usually applicable to secondary loops.
...ata Guidelines	**Preferred Method:**	Measure pump power / current and differential pressures at different operating modes (as-found, dead head, wide open, etc.). For verification, if measure consisted of an impeller trim, redo deadhead test to verify new impeller size and note final balanced position of discharge valve. If measure consisted of adding a VFD, see Finding Type 21.	Trend pump motor power / current. For variable volume systems, also trend water flow. For constant volume systems, spot measure water flow or pump differential pressure.	Trend motor power / current and any other relevant independent variables (e.g., OAT, IGV position). For verification phase, trend fan speed and other relevant independent variables.	Trend motor power / current and any other relevant independent variables (e.g., OAT, temperature differential). For verification phase, trend pump speed and other relevant independent variables.

		...uipment Scheduling and Enabling: No demand savings unless new schedule turns off equipment ...ing building peak demand period. kWh savings are proportional to the pre- and post-measure operation hours.			Economizer/Outside Air Loads: Properly operating economizers will reduce de... temperature if the baseline economizer is introducing excessive outside air into the build... reduce demand and energy consumption under low ambient conditions.
		Finding Type 1	Finding Type 2	Finding Type 3	Finding Type 4
Finding Type		Time of Day enabling is excessive	Equipment is enabled regardless of need, or such enabling is excessive	Lighting is on more hours than necessary.	Economizer Operation – Inadequate Free Cooling (Damper failed in minimum or closed position, economizer setpoints not optimized, Night Purge not enabled)
Baseline Data and Post-Implementation Verification D...	**Other Allowable Method(s):** Note: When planning on using any of these non-preferred methods for baseline data, contact the Program first for approval.	Trend command signal during all operating modes, visually spot verify that equipment / lighting operation matches commanded state. Document observations. Provide screenshots of equipment / lighting operating schedule. Provide screenshots of equipment / lighting operating status in all operating modes. Provide screenshots of equipment / lighting operating schedule. Visually spot verify that equipment / lighting operation matches commanded state. Document observations.	Trend command signal and relevant independent variables during all operating modes, visually spot verify that equipment / lighting operation matches commanded state. Document observations. Provide screenshots of equipment / lighting operating status and relevant independent variables in all operating modes. Provide screenshots of equipment / lighting operating schedule, or command signal in all operating modes. Visually spot verify that equipment / lighting operation matches commanded state. Document observations.	Trend command signal during representative day types, visually spot verify that lighting operation matches commanded state. Document observations. Provide screenshots of lighting operating schedule and operating status in all operating modes. Provide screenshots of lighting operating schedule and operating command signal in all operating modes. Visually spot verify that lighting operation matches commanded state. Document observations.	Trend SAT, OAT, RAT, economizer damper command, and call for cooling. For implementation verification, if trending of temperatures is inappropriate (e.g., if OA is too high or too low to observe economizer operation), perform functional testing. Document observations. For the baseline, if OA dampers are non-functional and fully closed, document conditions with a photo at different operating conditions (e.g., different OA temps). Then for verification, perform trending / functional testing or provide screenshots. Provide screenshots of system performance during all relevant operating conditions. Visually spot verify that system performance matches commanded state, where applicable. Document observations. Trend economizer damper command signal and relevant independent variables (e.g., OAT and RAT), visually spot verify that damper moves to commanded position. Perform tests at multiple damper positions and multiple fan speeds (if a VAV system) to establish the relationship between damper position and outside air fraction. Document all observations.
	Other Allowable Method(s) for Low Savings Measures (<25,000 kWh):	Provide screenshots of equipment / lighting operating schedule, and visually spot verify that equipment / lighting operation matches commanded state. Document observations. Provide relevant before / after photos.	Provide screenshots of control logic, and visually verify that equipment / lighting operation matches commanded state. Document observations. Provide relevant before / after photos.	Provide screenshots of lighting operating schedule, and visually spot verify that lighting is operating as expected. Document observations. Provide relevant before / after photos.	Provide screenshots of controls sequences, if measure consists solely of modifying sequences. Provide relevant before / after photos.

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		mand and energy consumption during periods of high ambient ling. If the baseline economizer is closed, fixing the economizer will	**Controls Problems:** Eliminating simultaneous heating and cooling reduces both the electricity required for heating, as well as the cooling required to offset the heat. Calculation methods for sensor/thermostat calibration and hunting and loop tuning are not easily generalized due to the wide range of potential failure modes.			**Controls (Setpoint Changes):** Optimizing setpoints can and can also reduce reheat requirements if excessive air is provi	
		Finding Type 5	**Finding Type 6**	**Finding Type 7**	**Finding Type 8**	**Finding Type 9**	**Finding Type 10**
Finding Type		**Over-Ventilation – Outside air damper failed in an open position. Minimum outside air fraction not set to design specifications or occupancy.**	**Simultaneous Heating and Cooling is present and excessive**	**Sensor/Thermostat needs calibration, relocation/shielding, and/or replacement**	**Controls "hunt" and/or need Loop Tuning or separation of heating/cooling setpoints**	**Zone setpoint setup/setback are not implemented or are sub-optimal.**	**Fan Speed Doesn't Vary Sufficiently**
Baseline Data and Post-Implementation Verification Da	**Other Allowable Method(s):** Note: When planning on using any of these non-preferred methods for baseline data, contact the Program first for approval.	Perform functional testing to simulate system performance at different relevant independent variable values (e.g., OAT, CO_2). Document observations. For the baseline, if OA dampers are non-functional and fully closed, document conditions with a photo at different operating conditions (e.g., different OA temps). Then for verification, perform trending / functional testing or provide screenshots. Provide screenshots of system performance during all relevant operating conditions. Visually spot verify that system performance matches commanded operation, where applicable. Document observations. Trend economizer damper command signal and relevant independent variables (e.g., OAT, CO_2), visually spot verify that damper moves to commanded position. Perform tests at multiple damper positions and multiple fan speeds (if a VAV system) to establish the relationship between damper position and outside air fraction. Document all observations.	Perform functional testing, including spot measurements. Provide screenshots of system performance during all relevant operating conditions. Visually spot verify that system performance matches commanded state, where applicable. Document observations.	Perform spot measurements at multiple times of day and under various operating scenarios (as appropriate), to make certain that solar effects or flow variations don't cause errors in readings. Document observations / readings.	Trend loop set-point, control feedback data inputs, and performance of affected equipment.	Provide screenshots of zone temperatures, zone temperature setpoints, and HVAC system status during each system operating mode.	Provide screenshots of relevant points (e.g., static pressure setpoint) and fan speed. If setpoint is reset, provide screenshots at all relevant operating conditions. Perform functional testing, including spot measurements.
	Other Allowable Method(s) for Low Savings Measures (<25,000 kWh):	Provide screenshots of controls sequences, if measure consists solely of modifying sequences. Provide relevant before / after photos.	Provide screenshots of controls sequences, if measure consists solely of modifying sequences.	Provide screenshots showing measured temperatures, along with calibrated reading. Provide relevant before / after photos.	(none)	Provide screenshots of zone temperature setpoints during each system operating mode.	(none)

		reduce energy consumption by reducing fan energy requirements, ded to zones with low internal loads.		**Controls (Reset Schedules):** Resetting the supply air temperature can allow more economizer operation, both water-side, since a higher CHW temperature may be allowable, and air side, due to a higher allowable mixed air temperature. Resetting the CHW temperature can improve the efficiency of the chiller, and also allow longer operation of the water-side economizer. However, changing the reset schedules may affect fan operation, which can offset the efficiency increases of primary cooling equipment.				**Equipment Efficiency Impro** unchanged. The savings in demand equipment does not run during the p measure demand.
		Finding Type 11	**Finding Type 12**	**Finding Type 13**	**Finding Type 14**	**Finding Type 15**	**Finding Type 16**	**Finding Type 17**
Finding Type		**Pump Speed Doesn't Vary Sufficiently**	**VAV Box Minimum Flow Setpoint is higher than necessary**	**HW Supply Temperature Reset is not implemented or is sub-optimal**	**CHW Supply Temperature Reset is not implemented or is sub-optimal**	**Supply Air Temperature Reset is not implemented or is sub-optimal**	**Condenser Water Temperature Reset is not implemented or is sub-optimal**	**Daylighting Control needs optimization**
Baseline Data and Post-Implementation Verification D	**Other Allowable Method(s):** Note: When planning on using any of these non-preferred methods for baseline data, contact the Program first for approval.	Provide screenshots of relevant points (e.g., differential pressure setpoint) and pump speed. If setpoint is reset, provide screenshots at all relevant operating conditions. Perform functional testing, including spot measurements.	Determine reheat at minimum VAV box flow through functional testing. Provide screenshots of VAV box and fan system performance at multiple operating conditions. Document observations.	(none)	(none)	(none)	(none)	Functionally test daylighting system. Note locations of sensors and lighting zones. Document observations / results.
	Other Allowable Method(s) for Low Savings Measures (<25,000 kWh):	(none)	(none)	(none)	(none)	(none)	(none)	(none)

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		Finding Type 18	**Finding Type 19**	**Finding Type 20**	**Finding Type 21**
Finding Type		**Pump Discharge Throttled**	**Over-Pumping**	**VFD Retrofit - Fans**	**VFD Retrofit - Pumps**
Baseline Data and Post-Implementation Verification D	**Other Allowable Method(s):** Note: When planning on using any of these non-preferred methods for baseline data, contact the Program first for approval.	(none)	Trend pump speed. For variable volume systems, also trend water flow. For constant volume systems, spot measure water flow or pump differential pressure during all relevant operating conditions. Perform functional testing, including spot measurements, at all relevant operating conditions. For constant volume systems, submit screenshots of system performance and spot measure pump differential pressure during all relevant operating conditions.	For baseline, spot measure fan motor power / current. Note system performance, document observations. For verification, submit photo of installed VFD. Submit screenshots of system performance, showing speed of VFD. Perform functional testing, including spot measurements where necessary, to simulate system performance.	For baseline, spot measure pump motor power / current. Note system performance, document observations. For verification, submit photo of installed VFD. Submit screenshots of system performance, showing speed of VFD. Perform functional testing, including spot measurements where necessary, to simulate system performance.
	Other Allowable Method(s) for Low Savings Measures (<25,000 kWh):	(none)	Provide screenshots of controls sequences.	(none)	(none)

		Finding Type 1	Finding Type 2	Finding Type 3	Finding Type 4
		quipment Scheduling and Enabling: No demand savings unless new schedule turns off equipment ing building peak demand period. kWh savings are proportional to the pre- and post-measure operation hours.			**Economizer/Outside Air Loads**: Properly operating economizers will reduce de temperature if the baseline economizer is introducing excessive outside air into the build reduce demand and energy consumption under low ambient conditions.
Finding Type		**Time of Day enabling is excessive**	**Equipment is enabled regardless of need, or such enabling is excessive**	**Lighting is on more hours than necessary.**	**Economizer Operation – Inadequate Free Cooling (Damper failed in minimum or closed position, economizer setpoints not optimized, Night Purge not enabled)**
Calculating Energy, Demand, and Cost Savings	**Examples / Guidelines:**	Determine existing schedules of equipment to be rescheduled. Measure equipment demand. Determine revised schedule, and calculate savings (Equipment demand * Difference between new and baseline operating hours). Note that other values beyond those mentioned above may need to be trended / spot measured for the savings calcs (e.g., lighting kW).	Determine existing schedules of equipment to be rescheduled. Determine equipment demand. If equipment demand varies with ambient conditions, develop relationship between demand and ambient conditions. Estimate optimum start/stop schedule for each month and compare to the original schedule to calculate energy savings (Equipment demand * Difference between new and baseline monthly operating hours). Note that other values beyond those mentioned above may need to be trended / spot measured for the savings calcs (e.g., lighting kW).	Determine existing lighting schedules. Develop load shapes for representative day types. Determine revised schedule and load shapes. Calculate savings based on load shapes and day types (kW savings * annual hours per day type). Note that other values beyond those mentioned above may need to be trended / spot measured for the savings calcs (e.g., lighting kW).	Determine the air handler airflow at different independent variables (e.g., outside air temperatures). This can be estimated using design capacities and fan speed or power / current monitoring. Determine baseline and optimum economizer operation. Use bin data of outside air temperature or wet-bulb temperature to calculate savings using the difference between the baseline and optimum mixed air temperature/enthalpy, airflow, and estimated or measured cooling plant efficiency. Account for OA and RA damper leakage in the savings calculations (e.g., 5% leakage for older dampers with no seals, 1% leakage for newer dampers with blade and jamb seals). Note that other values beyond temperatures may need to be trended / measured for the savings calcs (e.g., chiller kW/ton, fan speeds). For Night Purge measures, the electric savings comes from a reduction in chiller plant energy usage. Savings is dependent on the thermal mass of the building, chiller plant efficiency, supply and return / exhaust fan power, and the night purge control scheme. An hourly (8760) analysis, spreadsheet or whole building simulation, can be performed to estimate the nighttime space temperatures, chilled water plant energy consumption, and fan energy consumption in the baseline case and the ECM case. Note: The kWh savings for night purge measures is typically 2-8% of the baseline annual cooling energy consumption.

	...mand and energy consumption during periods of high ambient ...ling. If the baseline economizer is closed, fixing the economizer will	**Controls Problems:** Eliminating simultaneous heating and cooling reduces both the electricity required for heating, as well as the cooling required to offset the heat. Calculation methods for sensor/thermostat calibration and hunting and loop tuning are not easily generalized due to the wide range of potential failure modes.			**Controls (Setpoint Changes):** Optimizing setpoints can ... and can also reduce reheat requirements if excessive air is provi...	
	Finding Type 5	**Finding Type 6**	**Finding Type 7**	**Finding Type 8**	**Finding Type 9**	**Finding Type 10**
Finding Type	**Over-Ventilation – Outside air damper failed in an open position. Minimum outside air fraction not set to design specifications or occupancy.**	**Simultaneous Heating and Cooling is present and excessive**	**Sensor/Thermostat needs calibration, relocation/shielding, and/or replacement**	**Controls "hunt" and/or need Loop Tuning or separation of heating/cooling setpoints**	**Zone setpoint setup/setback are not implemented or are sub-optimal.**	**Fan Speed Doesn't Vary Sufficiently**
Calculating Energy, Demand, and Cost Savings – **Examples / Guidelines:**	Determine the baseline minimum outside air fraction at different outside air temperatures. Determine optimum minimum outside air fraction and schedule. Use bin data of outside air temperature to calculate savings using the difference between the baseline and optimum mixed air temperature, airflow, and estimated or measured cooling plant efficiency. Note that other values beyond temperatures may need to be trended / measured for the savings calcs (e.g., valve positions, fan speeds).	Quantify both the wasted heating energy and the wasted cooling energy. For gas heat, determine the load on the heating coil and use the boiler efficiency at part load to determine the wasted gas. The wasted cooling energy is equal to the excess heating energy. The cooling electrical energy is calculated using the cooling plant efficiency. Note that other values beyond temperatures may need to be trended / measured for the savings calcs (e.g., chiller kW/ton).	Determine the type of energy saving opportunity this problem would create, and calculate savings by comparing the demand and energy consumption of the system with the uncalibrated sensor to the system with the calibrated sensor.	Determine optimum control loop strategy. Calculate savings based on revised control scheme and effect on equipment.	Monitor the operation of the unit serving the zone during unoccupied periods to obtain information regarding the system on/off time, compared to the zone temperature set point deadband and outside air temperature. Develop a relationship between unit run time and outside air temperature. Calculate reduced unit operation with "increased deadband" during setback/setup periods, and associated savings. Note that other values beyond temperatures may need to be trended for the savings calcs (e.g., DAT, OAT, heating/cooling mode).	Focus of this measure is on fan energy savings. Determine the minimum static pressure setpoint possible to maintain design flow conditions. Empirically determine the relationship between static pressure and fan energy at existing setting and proposed setting. (As an option, RCx Provider may calculate additional heating and cooling plant savings due to reduced airflow.) If possible, use the terminal unit commands or position feedback to reset (further reduce) the setpoint during off-design conditions. Adjust the setpoint to maintain at least one terminal unit near full open. Airflow can be calculated using measured fan power, speed, and duct static pressure values, if no design drawings are present. Note that other values beyond temperatures may need to be trended for the savings calcs (e.g., OAT).

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		reduce energy consumption by reducing fan energy requirements, ded to zones with low internal loads.		**Controls (Reset Schedules):** Resetting the supply air temperature can allow more economizer operation, both water-side, since a higher CHW temperature may be allowable, and air side, due to a higher allowable mixed air temperature. Resetting the CHW temperature can improve the efficiency of the chiller, and also allow longer operation of the water-side economizer. However, changing the reset schedules may affect fan operation, which can offset the efficiency increases of primary cooling equipment.				**Equipment Efficiency Impro** unchanged. The savings in demand equipment does not run during the p measure demand.
		Finding Type 11	**Finding Type 12**	**Finding Type 13**	**Finding Type 14**	**Finding Type 15**	**Finding Type 16**	**Finding Type 17**
Finding Type		**Pump Speed Doesn't Vary Sufficiently**	**VAV Box Minimum Flow Setpoint is higher than necessary**	**HW Supply Temperature Reset is not implemented or is sub-optimal**	**CHW Supply Temperature Reset is not implemented or is sub-optimal**	**Supply Air Temperature Reset is not implemented or is sub-optimal**	**Condenser Water Temperature Reset is not implemented or is sub-optimal**	**Daylighting Control needs optimization**
Calculating Energy, Demand, and Cost Savings	**Examples / Guidelines:**	Determine the minimum differential pressure setpoint possible to maintain design flow conditions. Empirically determine the relationship between differential pressure and pump energy at existing setting and proposed setting. (As an option, RCx Provider may calculate additional heating and cooling plant savings due to reduced water flow.) If possible, use the valve commands or position feedback to reset (further reduce) the setpoint during off-design conditions. Adjust the setpoint to maintain at least valve near full open. For chiller plants with low ΔT, a goal is to minimize flow to increase the ΔT across the chiller, thereby reducing the number of chillers and (primary) pumps necessary to satisfy the load. Note that other values beyond temperatures may need to be trended for the savings calcs (e.g., OAT).	Determine the existing and optimized minimum setpoints. Calculate reduced reheat at reduced minimum flow setpoint, and subsequent cooling and fan energy savings. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., fan speeds, chiller kW/ton, OAT).	Determine optimal reset temperature based on required system temperatures. Calculate reduced energy consumption of boiler with HW reset (energy savings from reduced piping and boiler shell heat loss due to cooler HWS / HWR temps), from engineering heat transfer calculations or data from functional tests. Account for potential increased pump usage (cooler HWS temps may require increased flow to deliver same amount of heating). Engineering calcs: estimate piping length and amount of insulation to calculate heat transfer from piping. Functional test: with no heating load (heating control valves in 100% bypass), trend / measure HWR temps at various HWS temps to determine piping and boiler shell heat loss. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., pump speeds).	CHW supply temp reset based on OAT or valve position. Determine optimal reset temperature based on required system temperatures. Calculate reduced energy consumption of chiller plant at reset CHW temperature, and subsequent increase / decrease in fan and pump energy. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., fan and pump speeds).	Determine energy savings from cooling plant and reduced reheat at zone level, and potential fan energy penalty due to increased airflow at warmer supply air temperatures. Airflow can be calculated using design fan flow and trended fan speeds. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., fan speeds).	Condenser water supply temp reset based on differential with wet-bulb OAT. May additionally be based on load. Determine optimal reset temperature based on required system temperatures, and chiller temperature requirements. Calculate reduced energy consumption of chiller plant due to improved efficiency at lower condenser water temperatures, and subsequent increase in cooling tower fan energy. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., chiller kW/ton).	Determine existing lighting operation. Develop load shapes for representative occupancy and ambient light levels. Determine revised operation and load shapes. Calculate savings based on load shapes and proposed operation. (kW savings * annual hours per day type).

		...vements / Load Reduction: Pre- and post-retrofit schedules remain ... is the difference between the new and old equipment demand, unless the ... eak demand period. kWh savings are proportional to the pre- and post-		**Variable Frequency Drives (VFD):** Variable Frequency Drives allow pumps and fans to operate at lower speeds. This is generally a more energy efficient method to control capacity than using vanes on fans, or discharge or 3-way valves on pumps.	
		Finding Type 18	**Finding Type 19**	**Finding Type 20**	**Finding Type 21**
Finding Type		**Pump Discharge Throttled**	**Over-Pumping**	**VFD Retrofit - Fans**	**VFD Retrofit - Pumps**
Calculating Energy, Demand, and Cost Savings	**Examples / Guidelines:**	Use pump curves to determine pump motor savings due to reduced pump head pressure, assuming the valve at the discharge of the pump wide open and pump impeller trimmed. Estimate annual hours of operation and calculate potential savings.	Use pump curve to determine reduced pump power at reduced speed. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., chiller operation).	Use power / current as a surrogate measurement of motor load. Compare existing fan curve to VFD fan curve to estimate annual energy savings. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., temperatures, cooling load).	Trend temperature differential and spot measurement of flow to determine existing load. Compare existing load shape to VFD pump curve to estimate annual energy savings. Note that other values beyond those mentioned above may need to be trended for the savings calcs (e.g., temperatures, cooling load).

		[Eq]uipment Scheduling and Enabling: No demand savings unless new schedule turns off equipment [dur]ing building peak demand period. kWh savings are proportional to the pre- and post-measure operation hours.			**Economizer/Outside Air Loads**: Properly operating economizers will reduce de[mand]... temperature if the baseline economizer is introducing excessive outside air into the build[ing]... reduce demand and energy consumption under low ambient conditions.
		Finding Type 1	**Finding Type 2**	**Finding Type 3**	**Finding Type 4**
Finding Type		**Time of Day enabling is excessive**	**Equipment is enabled regardless of need, or such enabling is excessive**	**Lighting is on more hours than necessary.**	**Economizer Operation – Inadequate Free Cooling (Damper failed in minimum or closed position, economizer setpoints not optimized, Night Purge not enabled)**
	Peak Demand Opportunity:	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.	Occupancy sensors may reduce peak demand if implemented in areas such as cafeterias.	Opportunity for peak demand reduction very low unless economizer was observed in a failed-open position (Finding Type 5). For Night Purge measures, opportunity for peak demand reduction exists as the purpose of this control method is to pre-cool the building and reduce the load on the chiller(s).

	mand and energy consumption during periods of high ambient ling. If the baseline economizer is closed, fixing the economizer will	**Controls Problems:** Eliminating simultaneous heating and cooling reduces both the electricity required for heating, as well as the cooling required to offset the heat. Calculation methods for sensor/thermostat calibration and hunting and loop tuning are not easily generalized due to the wide range of potential failure modes.			**Controls (Setpoint Changes):** Optimizing setpoints can and can also reduce reheat requirements if excessive air is provi	
	Finding Type 5	**Finding Type 6**	**Finding Type 7**	**Finding Type 8**	**Finding Type 9**	**Finding Type 10**
Finding Type	**Over-Ventilation – Outside air damper failed in an open position. Minimum outside air fraction not set to design specifications or occupancy.**	**Simultaneous Heating and Cooling is present and excessive**	**Sensor/Thermostat needs calibration, relocation/shielding, and/or replacement**	**Controls "hunt" and/or need Loop Tuning or separation of heating/cooling setpoints**	**Zone setpoint setup/setback are not implemented or are sub-optimal.**	**Fan Speed Doesn't Vary Sufficiently**
Peak Demand Opportunity:	Determine reduced cooling coil load due to reduced outside air during utility system peak.	Opportunity for peak demand reduction depends on time of simultaneous heating and cooling. For leaking HW valves, calculate reduced cooling coil load and subsequent reduced cooling plant demand. Note that there will not be any savings unless the system has sufficient capacity (and provides sufficient comfort) in the baseline situation, otherwise the increased capacity from elimination of the extra load will go toward comfort rather than demand savings.	Opportunity for peak demand reduction very low.	May be opportunity for peak demand reduction if cycling is severe and affects large equipment.	Opportunity for peak demand reduction very low.	May be opportunity for peak demand reduction if fan speeds are lowered significantly, even during on-peak conditions.

		reduce energy consumption by reducing fan energy requirements, ded to zones with low internal loads.		**Controls (Reset Schedules):** Resetting the supply air temperature can allow more economizer operation, both water-side, since a higher CHW temperature may be allowable, and air side, due to a higher allowable mixed air temperature. Resetting the CHW temperature can improve the efficiency of the chiller, and also allow longer operation of the water-side economizer. However, changing the reset schedules may affect fan operation, which can offset the efficiency increases of primary cooling equipment.				**Equipment Efficiency Impro** unchanged. The savings in demand equipment does not run during the p measure demand.
		Finding Type 11	**Finding Type 12**	**Finding Type 13**	**Finding Type 14**	**Finding Type 15**	**Finding Type 16**	**Finding Type 17**
Finding Type		**Pump Speed Doesn't Vary Sufficiently**	**VAV Box Minimum Flow Setpoint is higher than necessary**	**HW Supply Temperature Reset is not implemented or is sub-optimal**	**CHW Supply Temperature Reset is not implemented or is sub-optimal**	**Supply Air Temperature Reset is not implemented or is sub-optimal**	**Condenser Water Temperature Reset is not implemented or is sub-optimal**	**Daylighting Control needs optimization**
	Peak Demand Opportunity:	--	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.	Daylighting controls can reduce peak demand. Occupancy sensors may reduce peak demand if implemented in areas such as cafeterias.

		…vements / Load Reduction: Pre- and post-retrofit schedules remain … is the difference between the new and old equipment demand, unless the …eak demand period. kWh savings are proportional to the pre- and post-		**Variable Frequency Drives (VFD):** Variable Frequency Drives allow pumps and fans to operate at lower speeds. This is generally a more energy efficient method to control capacity than using vanes on fans, or discharge or 3-way valves on pumps.	
		Finding Type 18	**Finding Type 19**	**Finding Type 20**	**Finding Type 21**
Finding Type		**Pump Discharge Throttled**	**Over-Pumping**	**VFD Retrofit - Fans**	**VFD Retrofit - Pumps**
	Peak Demand Opportunity:	Good opportunity for peak demand savings.	Good opportunity for peak demand savings.	Opportunity for peak demand reduction very low.	Opportunity for peak demand reduction very low.