Final Optimization Report: Empowering Energy Efficiency in Existing Big-Box Retail/Grocery Stores

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List of Acronyms

AHU	air-handling unit
BAS	building automation system
CFM	cubic feet per minute
COP	coefficient of performance
CSE	Center for Sustainable Energy
CVRMSE	coefficient of variation for the root mean squared error
DEER	Database for Energy Efficiency Resources
DOE	U.S. Department of Energy
EEM	energy-efficiency measure
EIR	energy input ratio
EER	energy-efficiency ratio
HVAC	heating, ventilating, and air conditioning
HVAC/R	heating, ventilating, air conditioning, and refrigerating
LED	light-emitting diode
LPD	lighting power density
M&V	measurement and verification
MBH	thousand British thermal units per hour
NMBE	net mean bias error
NREL	National Renewable Energy Laboratory
PAT	Parametric Analysis Tool
RTU	rooftop unit
SMC	Software Motor Company

Executive Summary

Purpose

The Center for Sustainable Energy (CSE), in partnership with the National Renewable Energy Laboratory (NREL); TRC Energy Services; P2S Engineering, Inc.; Walmart; and five innovative technology providers, are to demonstrate the impact of an integrated suite of pre-commercial energy-efficiency technologies in a large existing retail building located within an inland disadvantaged community. Proposed technology packages include three categories of advanced energy-efficiency solutions: heating, ventilating, air conditioning, and refrigerating (HVAC/R); lighting; and integrated system- and building-level controls. The project is designed to impact Walmart's future store specifications, which can be replicated and deployed in other buildings across California with similar end-use and system characteristics. The following technologies were considered for this project:

- *DualCool*: HVAC evaporative cooling
- *Software Motor Company (SMC)* [1]: HVAC/R fan motor
- *I2S*: DC LED lighting
- *LocBit*: Building energy management and optimization
- *Saya*: DualCool water monitoring.

Goal

The primary goal of the project is to demonstrate the ability of the suite of pre-commercial technologies to deliver site electricity savings of 20% or greater. NREL is providing a key technical support role for the project, in addition to undertaking a lead role for performing energy modeling and impact analysis of the pre-commercial technologies deployed in the project.

Approach

NREL utilized the U.S. Department of Energy's (DOE's) OpenStudio modeling platform for developing a calibrated baseline model for the selected Walmart store. OpenStudio was also leveraged for modeling the energy-efficiency measures (EEMs) and selecting the most impactful EEM package that meets Walmart's requirements.

Overview of Simulation Results

Through DualCool's innovative heating, ventilating, and air-conditioning (HVAC) evaporative-cooling technology and SMC's high-efficiency motors and smart internet-of-things controls, HVAC/R retrofits are expected to yield ~8.9% reduction in site electricity consumption. I2S's DC-powered light-emitting diode (LED) lighting system retrofit contributes to ~10.9% in annual site electricity savings. LocBit's integrated building-level control and supervisory system can offer an additional 1.9% in permanent electricity savings through optimized controls and set-point adjustments. The selected technologies are expected to achieve the project target of 20% in whole-building-site electricity savings. However, while modeled savings estimates are useful in understanding the relative impacts of each energy-efficiency technology, actual operations of the

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[1] At the time of writing, SMC rebranded to Turntide Technologies

store may be different than those specified in as-built drawings and schedules. As a result, actual normalized metered energy consumption savings calculations may differ from modeling predictions.

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Introduction

The Center for Sustainable Energy (CSE), in partnership with the National Renewable Energy Laboratory (NREL); TRC Energy Services; P2S Engineering, Inc.; Walmart; and five innovative technology providers, are to demonstrate the impact of an integrated suite of pre-commercial energy-efficiency technologies in a large existing retail building located within an inland disadvantaged community. Proposed technology packages include three categories of advanced energy-efficiency solutions: heating, ventilating, air conditioning, and refrigerating (HVAC/R); lighting; and integrated system- and building-level controls. The selected site is a 20-year-old, 134,285-square-foot Walmart Supercenter located in West Covina, California, within Southern California Edison's (SCE) service territory. The project is designed to impact Walmart's future store specifications, which can be replicated and deployed in other buildings across California with similar end-use and system characteristics.

NREL is providing a key technical support role for the project, in addition to undertaking a lead role for performing energy modeling and impact analysis of the pre-commercial technologies deployed in the project. This report summarizes the procedures used by NREL for developing the baseline model, calibrating the baseline model with monthly utility data, tuning the model with hourly baseline measurement and verification (M&V) data, modeling the pre-commercial energy-efficiency measures (EEMs) associated with each technology, and quantifying the energy savings impact of the integrated suite of technologies to be deployed in the selected Walmart store. The savings are determined and quantified by integrating the EEM models with the calibrated baseline model, performing parametric modeling and optimization of the EEMs, and analyzing and selecting the most impactful and economical EEM package that meets Walmart requirements.

Overall Approach

NREL utilized the U.S. Department of Energy's (DOE's) OpenStudio modeling platform, which builds on DOE's EnergyPlus simulation engine and includes a collection of software tools that support whole-building energy modeling.[2,3] OpenStudio is an open-source platform for the creation of desktop application or web services, which enables the rapid creation of energy models for building design, retrofit performance assessment, and load analysis at multiple scales. Models may be built with few or many inputs depending on the need for precision. Among these software tools are the OpenStudio Application and the Parametric Analysis Tool (PAT). OpenStudio Application is a fully featured graphical interface that facilitates construction and inspection of OpenStudio models including envelope, loads, schedules, and heating, ventilation, and air conditioning (HVAC).

Some of the more useful features in OpenStudio are the built-in libraries, as well as the online Building Component Library. These libraries contain standard definitions for constructions, end uses, schedules, and more that are consistent with ASHRAE Standard 90.1, California Energy Commission (CEC) Title 24, and California Public Utilities Commission (CPUC) Database for

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[2] https://www.openstudio.net/

[3] https://energyplus.net/

Energy Efficiency Resources (DEER). Use of library definitions for specific building types, vintages, and climate zones greatly accelerates the creation of building energy models, while simultaneously reducing the opportunity for data input entry.

Another of the platform's strengths is its modular approach to modeling and analysis automation. Such tasks are easily extended via small scripts called "OpenStudio Measures," so named because they are most often used to represent energy-efficiency measures.[4] OpenStudio Measures can also be used to define custom reports, modifications to key model parameters for the purpose of calibration, or even wholesale creation of energy models from a few descriptive parameters. PAT leverages OpenStudio Measures to study the impact of energy-efficiency technologies applied to a baseline model. In addition, PAT can be used as a powerful optimization tool for new construction design or calibration of models using consumption data.

These and other features of the OpenStudio platform and example applications were used to produce a calibrated baseline energy model of the Walmart store studied in this project. The team also developed OpenStudio Measures representing the emerging technologies of interest and applied them to the baseline model to assess the savings contributions each might make towards the project's performance goal.

Baseline Model Development

This section outlines the procedures taken to develop the baseline model, which include reviewing and translating the available construction documents and drawings to OpenStudio building model inputs. Library data from the DEER 2014 and 2017 vintages were also used for initial inputs related to space type utilization and Title 24 construction definitions. These inputs were augmented with insights gained from numerous walkthroughs of the Walmart store in Covina.

Geometry and Envelope

In building energy modeling, thermal zones are served by HVAC systems and comprise one or more spaces. Proper identification and assignment of the thermal zones in buildings can have drastic implications on both building and energy modeling performance, in addition to implications on the building model computation time. Inspection of the site's mechanical system drawings describing rooftop units (RTUs) and air-handling units (AHUs) suggested the general placement and size of zones within the building. Floor space utilization (e.g., grocery versus pharmacy) also helped inform 34 zone boundaries, which are physically ambiguous given the openness of the sales floor. Moreover, identification and mapping of thermostat locations to HVAC systems through a detailed site walkthrough confirmed the model zoning. The identified thermostats and their locations within the store are shown in Appendix A. Figure 1 illustrates the overlay of mechanical systems and site floor plan drawings, along with the color-coded zone designations used in the energy model. Model zone numbers were arbitrarily assigned and have no correlation to any zoning nomenclature that may be used by the site's building automation system (BAS). Modeled zone numbers will be referenced throughout this report, particularly

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[4] http://nrel.github.io/OpenStudio-user-documentation/getting_started/about_measures/

when discussing equipment, mechanical systems, refrigeration, water systems, exhaust fan assignments, and locations within the store.

Figure 2 depicts the associated space types for each zone in the store, which define the general activities performed in these areas. Space types are defined by occupancy, lighting, miscellaneous electrical loads, and their associated schedules.

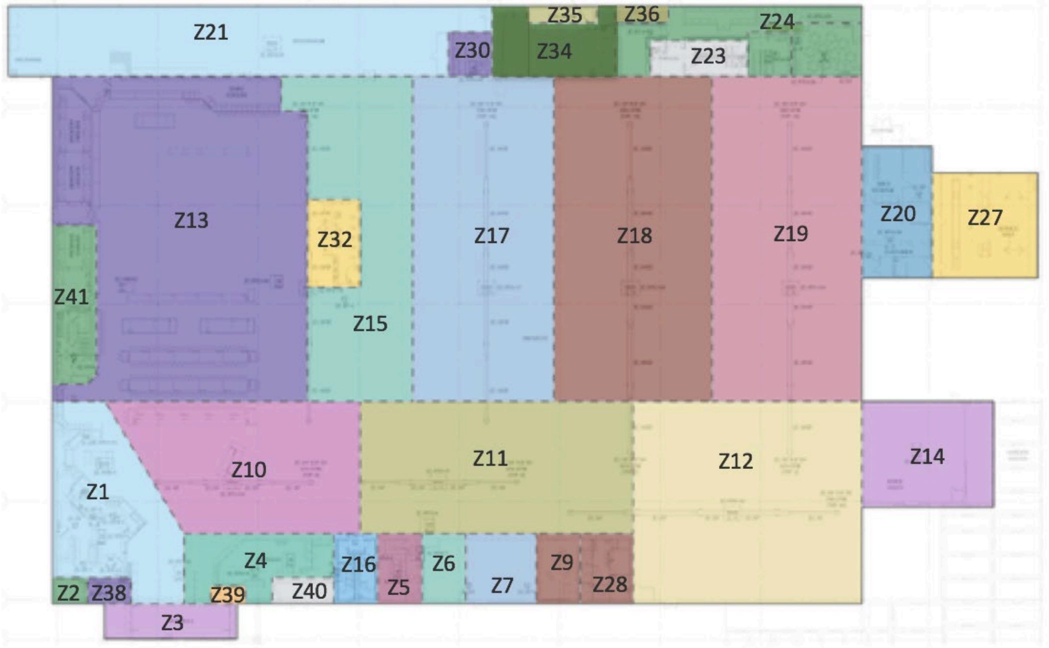

Figure 1: Zoned Walmart store based on an overlay of mechanical and site floor plan drawings

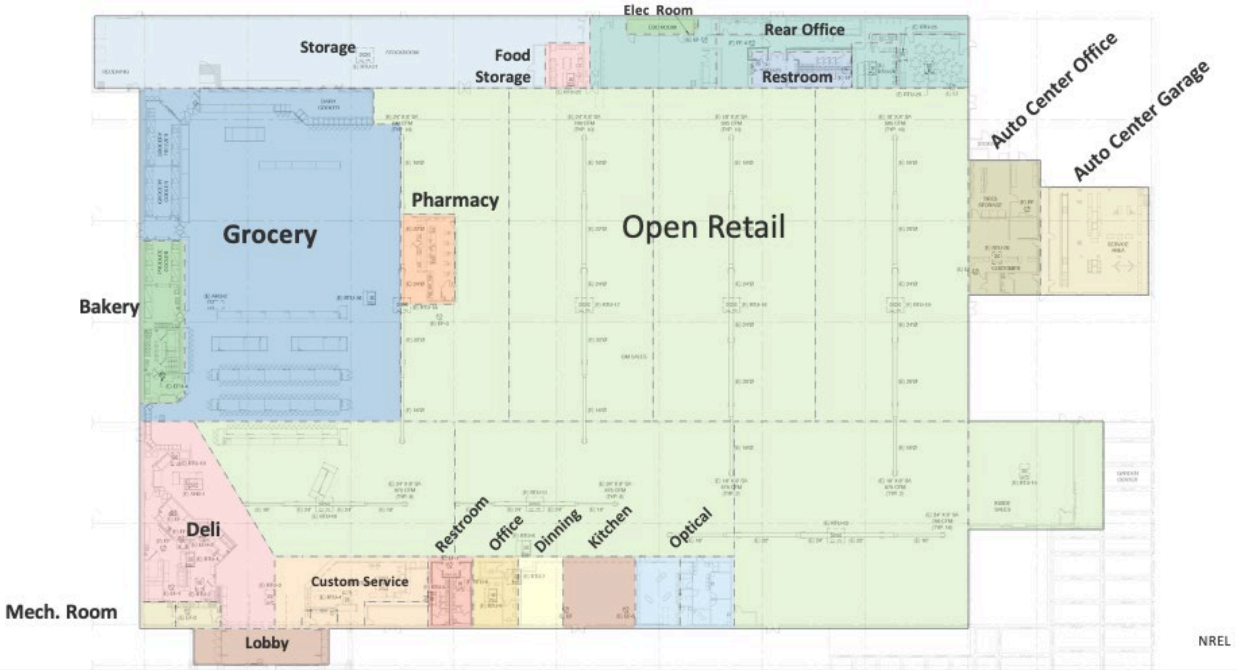

Figure 2: Space types corresponding to identified zones in Figure 1

Table 1 provides the percent breakdown by area of each space type relative to the entire store area. As mentioned previously, OpenStudio's built-in standards library was used to assign initial construction materials and internal loads (people, lighting, plug loads, equipment loads, and infiltration) and design outdoor air-ventilation requirements and schedules based on 1997 DEER assumptions corresponding to the store's vintage. Table 1 also identifies the mapping between the spaces in the store to the closest DEER building and activity types.

Table 1: Space Types Percent Breakdown by Area and Mapping to DEER Space/Building Type Standard (Gro = Grocery; RFF = Food Service; RtL = Large Retail)

Space Type Name	Percent of Total Store Area	DEER Building Type	DEER Activity Type
CorridorStairway_Rear	1.4%	Gro	CorridorStairway
CustomService_Front	1.5%	Gro	GrocSales
CustomService_Room_Front	0.1%	Gro	OfficeGeneral
GrocSales	56.0%	Gro	GrocSales
IndLoadDock_Front	0.3%	Gro	IndLoadDock
Kitchen-Bakery	1.0%	Gro	Kitchen
MechElecRoom_Rear	0.2%	Gro	MechElecRoom
OfficeGeneral_Rear	0.6%	Gro	OfficeGeneral
RefWalkInCool	16.0%	Gro	RefWalkInCool
Restroom_Front	0.5%	Gro	Restroom
StockRoom_Rear_Left	6.1%	Gro	StockRoom
Dining_MCD_Front	0.5%	RFF	Dining
Kitchen_MCD_Front	1.0%	RFF	Kitchen
LobbyWaiting_Front	0.8%	RFF	LobbyWaiting
OfficeGeneral_Front	0.6%	RFF	OfficeGeneral
StockRoom_MCD_Rear	0.3%	RFF	StockRoom
Break_Rear	0.7%	RtL	Break
Kitchen-Deli	4.1%	RtL	Kitchen
MechElecRoom_Front	0.3%	RtL	MechElecRoom
VisionCenter_Front	1.2%	RtL	OfficeGeneral
Restroom_Rear	0.8%	RtL	Restroom
RetailSales-AutoCenter	1.8%	RtL	RetailSales
AutoCenter_outdoor	2.5%	RtL	RetailSales
StockRoom_Rear_Right	1.2%	RtL	StockRoom
Work-Pharmacy	0.7%	RtL	Work

Use of the built-in library data provides reasonable input estimates that avoids a tedious and error-prone process of identifying and manually entering thousands of model parameters. Some of these model inputs were subsequently fine-tuned based on site-specific construction document data and store operation information obtained during numerous site visits. Other input parameters were subject to formal optimization during the calibration process presented later in the report.

The OpenStudio 3D geometry viewer of the final Walmart store baseline building model is shown in Figure 3. The vestibule store entrance shown at the bottom of the figure faces north.

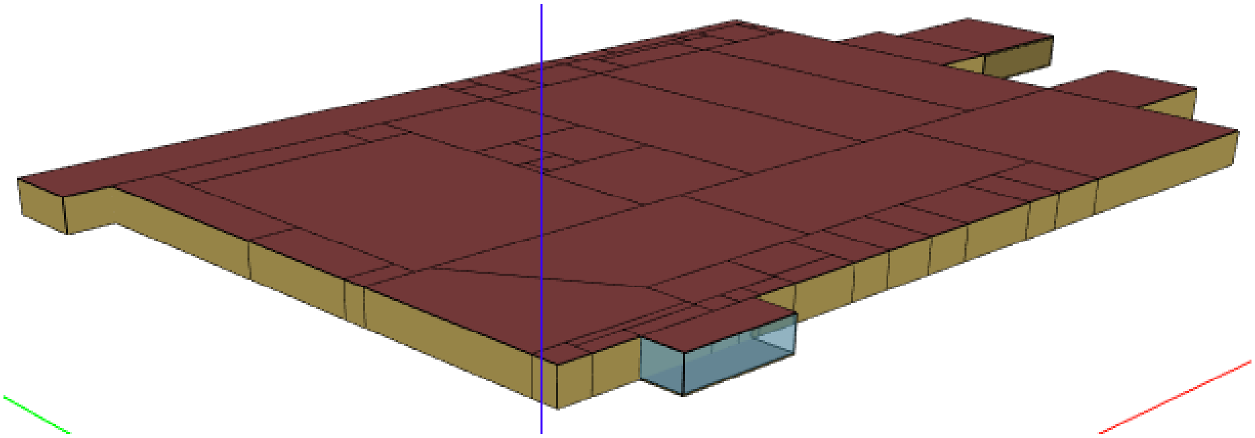

Figure 3: OpenStudio 3D viewer of Walmart store building model

Mechanical Systems

Rooftop Units

The selected Walmart store contains 27 RTUs serving various spaces in the building. These units range from 3 to 20 tons and utilize electricity for cooling and natural gas for heating. Table 2 is a complete list of the RTUs and their associated cooling capacities, heating capacities, energy-efficiency ratios (EERs), fan stages, supply fan operation mode (continuous/auto), supply fan volume flowrate, cooling stages, area served, and their assigned model zone numbers. All RTUs contain fully modulating economizers. In addition, demand-controlled ventilation based on occupancy schedules is enabled for RTUs 10, 12, 15, and 18. RTUs 1, 7, and 8 have two speed fan stages with first- and second-stage operations that coincide with compressor cooling stages. The first-stage fan speed ratio for RTUs 1, 7, and 8 is 0.55

Table 2: The 27 RTUs Serving the Various Zones within the Selected Walmart Store, and their Associated Cooling/Heating Capacities, Efficiencies, Areas Served, and Zone Assignments within the OpenStudio Model

RTU#	Model	Cooling (Nominal Tons)	Cooling Capacity (MBH) [a]	Heating Capacity (MBH)	EER	Fan Stages	Supply Fan CFM [b]	Supply Fan Operation	Cooling Stages	Area Served	Zone
1	LGB036	10	120	104	12.1	2	3,700	Continuous	2	Kitchen-Deli	1
2	LGB060	5	60	100	10.1	1	2,000	AUTO	1	MechElecRoom	38
3	LGB060	10	120	188	10	1	3,700	AUTO	2	LobbyWaiting	3
4	LGB060	5	60	100	10.1	1	2,000	AUTO	1	CustomService	39
5	LGB060	5	60	100	12.8	1	1,650	Continuous	1	OfficeGeneral	5
6	LGB060	3	36	60	10.5	1	1,500	AUTO	1	VisionCenter	28
7	LGB060	10	120	104	12.1	2	3,700	Continuous	2	McDonald	6
8	LGB060	10	120	104	12.1	2	3,700	Continuous	2	McDonald	7
9	LGB120	3	36	60	14.3	1	1,200	Continuous	1	VisionCenter	9
10	LGB120	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	10
11	LGB240	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	11
12	LGB240	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	12
13	LGB240	5	60	100	10.1	1	2,000	AUTO	1	Gro GrocSales	41
14	LGB240	10	120	188	10	1	3,700	AUTO	2	RtL RetailSales	14
15	LGB240	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	15
16	LGB240	3	36	60	14.3	1	1,200	Continuous	1	Pharmacy	32
17	LGB240	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	17
18	LGB240	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	18
19	SCA036	20	240	376	10	1	7,000	AUTO	2	RtL RetailSales	19
20	SGA036	5	60	100	10.1	1	2,000	AUTO	1	RtL RetailSales	20
21	SGA036	20	240	376	10	1	7,000	AUTO	2	StockRoom	21
22	SGA036	3	36	60	14.3	1	1,200	Continuous	1	StockRoom FF	33
23	SGA036	5	60	100	10.1	1	2,000	AUTO	1	RestRoom	23
24	SGA060	3	36	60	14.3	1	1,200	Continuous	1	Rear Office	24
25	SGA120	5	60	100	10.1	1	2,000	AUTO	1	Rear Office	37
26	SGA120	5	60	100	10.1	1	2,000	AUTO	1	Rear Office	26
27	SGA120	3	36	60	14.3	1	1,200	Continuous	1	Office	5

[a] Thousand Btu (British thermal units) per hour

[b] Cubic feet per minute

Additionally, four unitary gas heaters were added to the Auto center (Zone 27). Thermostat heating and cooling temperature set points are applied in the model based on the existing building automation system (Novar) specifications: 75°F for cooling and 68°F for heating during occupied store hours. Each RTU has its own occupied and unoccupied schedules, as dictated by the Novar system (see Appendix B). The RTU set points for unoccupied modes are 63°F for heating and 78°F for cooling. These set points remain constant throughout the year due to the continuous occupancy of the building.

The cooling-coil models in the EnergyPlus simulation engine use performance information at rated conditions, along with curve fits for variations in total capacity, energy input ratio, and part-load fraction to determine the performance of the units at part-load conditions.[5] Performance curves were developed at NREL's Thermal Test Facility on similar 10-ton Lennox LGE120H for its first- and second-stage operation. Both energy input ratio (EIR) and total cooling capacity modifier curves, as functions of both temperature and flow fraction for both first- and second-stage operation, are utilized as model inputs and presented in Appendix C.

Standard efficiency supply fan motors, based on unit models, were assigned to all RTUs and high part-load efficiency supply motors using the variable-frequency drive performance curve for AHUs.

All RTUs in the store have a fully modulated economizer with a high-limit dry-bulb set point of 70°F and a dewpoint set point of 48°F, which is activated globally by the Novar system. The economizer damper is fully modulated to maintain a supply-air set point at 55°F during cooling and to override the first stage of cooling. The outdoor fraction of all RTUs in the store is set to 10% of the design air flowrate, as specified in the Novar user interface. In addition, the outdoor air fraction for all RTUs was also confirmed in a formal model calibration effort, as described later in this report.

Air-Handling Units

The model inputs pertaining to the two AHUs serving the Deli/Produce and Grocery Sales areas were obtained from both the mechanical system drawing schedules, Novar user interface screenshots, and a site characterization report, and are presented in Table 3. These inputs include the cooling and heating capacities, thermal efficiency, EER, supply fan operation, supply fan volume flowrate, and the area and zones that it serves.

Table 3: AHU Specifications and OpenStudio Model Inputs

AHU #	Cooling (Nom Tons)	Heating Capacity (MBH)	Thermal Efficiency	EER	Supply Fan Operation	Supply Fan CFM	Area Served	Zone
1	25	325	80%	12.1	Continuous	3,500	Deli/Produce	1, 10
2	25	325	80%	12.1	Continuous	3,500	Grocery Sales	13, 41

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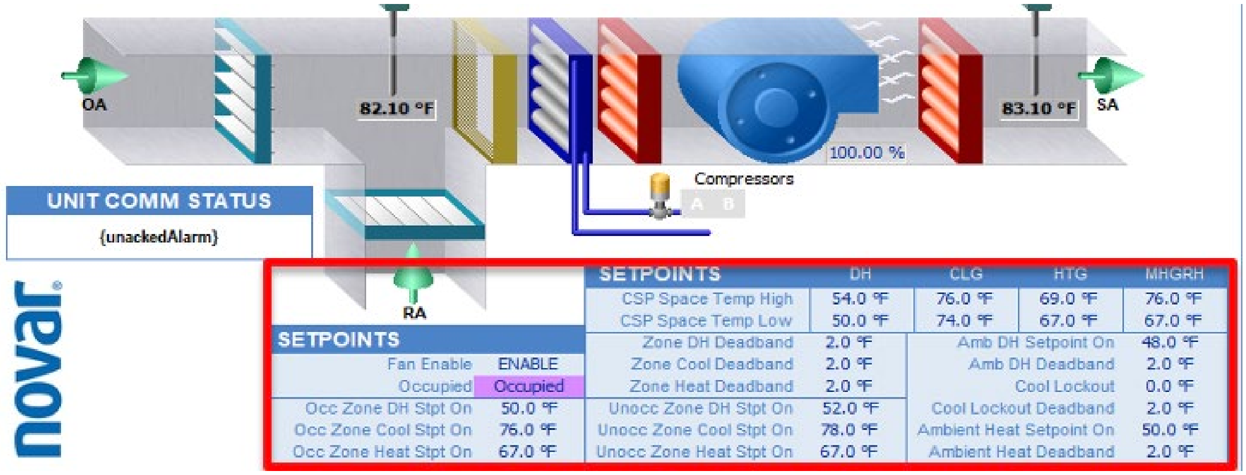
[5] Refer to the EnergyPlus *Engineering Reference* documentation for more detail: https://energyplus.net/sites/all/modules/custom/nrel_custom/pdfs/pdfs_v9.1.0/EngineeringReference.pdf

The AHUs run continuously to supply dehumidified and conditioned outdoor air as a dedicated outdoor air system (DOAS) unit. The AHUs have two-stage, variable-capacity compressors for dehumidifying and cooling, and a modulating gas coil for heating purposes. The dehumidifying process utilizes hot gas for reheating. The AHUs operate with the following set points:

- Zone set points:
  - 76°F cooling
  - 67°F heating
  - 52°F dewpoint
- Supply-air set points:
  - 76°F cooling
  - 67°F heating
  - 48°F dewpoint for outdoor ventilation.

A complete list of the of the Novar AHU set point settings is shown in Figure 4.



SETPOINTS	
Fan Enable	ENABLE
Occupied	Occupied
Occ Zone DH Stpt On	50.0 °F
Occ Zone Cool Stpt On	76.0 °F
Occ Zone Heat Stpt On	67.0 °F

SETPOINTS	DH	CLG	HTG	MHGRH
CSP Space Temp High	54.0 °F	76.0 °F	69.0 °F	76.0 °F
CSP Space Temp Low	50.0 °F	74.0 °F	67.0 °F	67.0 °F

Zone DH Deadband	2.0 °F	Amb DH Setpoint On	48.0 °F
Zone Cool Deadband	2.0 °F	Amb DH Deadband	2.0 °F
Zone Heat Deadband	2.0 °F	Cool Lockout	0.0 °F
Unocc Zone DH Stpt On	52.0 °F	Cool Lockout Deadband	2.0 °F
Unocc Zone Cool Stpt On	78.0 °F	Ambient Heat Setpoint On	50.0 °F
Unocc Zone Heat Stpt On	67.0 °F	Ambient Heat Deadband	2.0 °F

Figure 4: Novar AHU set points

Data for 5-ton RTUs from NREL's Thermal Test Facility, with similar functions to the store's AHUs, were leveraged to develop performance curves of two multispeed compressors with active dehumidification. The performance curves used to model the AHUs are provided in Appendix D.

Refrigeration

The selected Walmart store contains six refrigeration systems, with refrigerated cases and walk-in coolers in both Deli/Bakery and Grocery areas. The associated compressor and condenser unit specifications and OpenStudio model inputs are presented in Table 4.

Table 4: Refrigeration System Compressor and Condenser Unit Specifications and OpenStudio Model Inputs and Zone Assignments

Compressor Units			Condenser Units					
Rack ID	Refrigerant	Return Gas Temperature (°F)	Minimum Saturated Condensing Temperature (°F)	TD (°F)	Fan Qty	Fan Motor Horsepower	Area Served	Zone
A	R-404A	30	70	10	4	1	Rear Walk-ins & Cases	13
B	R-404A	30	70	10	4	1	Front Cases/ Deli/Bakery	13
C	R-404A	50	70	10	4	1	Front Cases/ Deli/Bakery	1, 10, 13
D	R-404A	50	70	10	4	1	Front Cases/ Deli/Bakery	1, 10, 13
E	R-404A	50	70	10	4	1	Rear Walk-ins/Cases	13
F	R-404A	50	70	10	4	1	Rear Walk-ins/Cases	13

The type of refrigerated cases, walk-in coolers, and associated defrost type, defrost power, fan power, case and walk-in evaporative temperatures, and case dimensions assigned to each refrigeration system is available in Appendix I.

The refrigeration condenser fans are controlled with a floating head pressure, where the compressor exit pressure and temperature are allowed to vary based on ambient conditions while preserving a minimum specified head pressure to maintain refrigerant flow through the system and for proper function of control valves. Head pressure must be sufficient to condense refrigerant at a specified temperature difference above ambient to allow heat rejection from the system to take place. Table 4 identifies the minimum condensing temperature and difference between condensing temperature and ambient temperature for all six installed refrigeration systems. As a demonstration of this type of control, a plot of the condensing temperature and ambient dry-bulb temperature from the baseline model is shown in Figure 5 for refrigeration system A during several days in January 2018. In this example, the condensing temperature follows the ambient temperature, minimizing compressor work.

Zone 13, which contains the refrigerated cases and walk-in coolers, requires no cooling and primarily requires heating due to the large cooled air spilled by the refrigerated cases into the zone. Simple heat exchanges were assigned between Zone 13 and adjacent zones in order to properly model the thermal zone interactions. EnergyPlus contains an "OtherEquipment" object[6]

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[6] https://bigladdersoftware.com/epx/docs/9-3/input-output-reference/group-internal-gains-people-lights-other.html#otherequipment

that is suitable for modeling these thermal zone interactions, which was leveraged in the baseline model for the store.

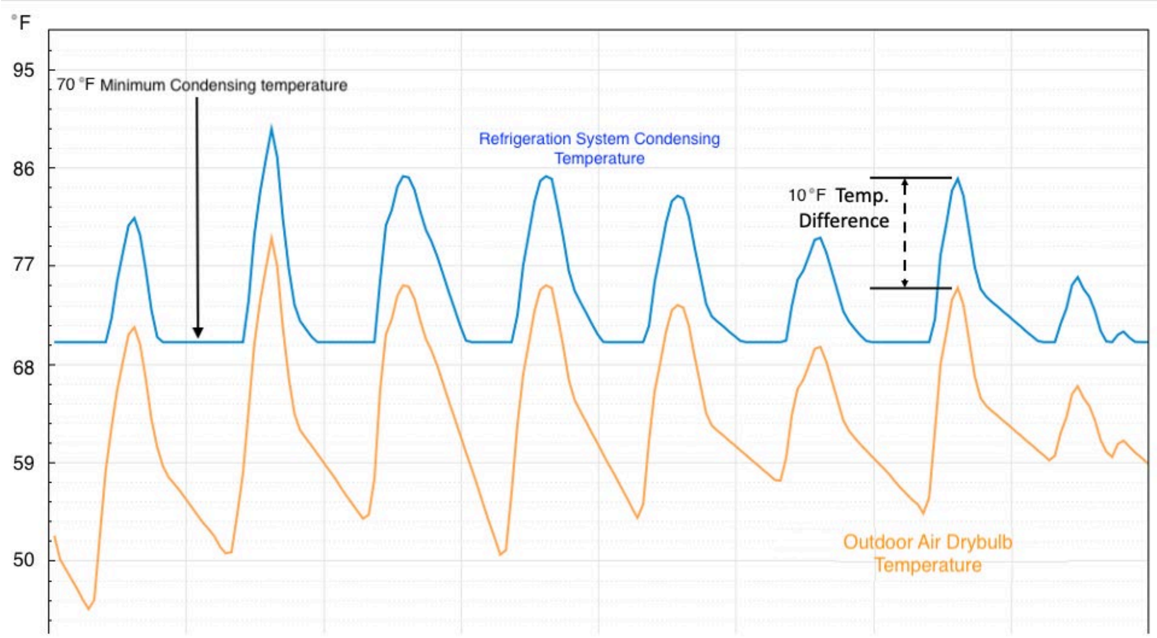

Figure 5: Floating head pressure control demonstration for refrigeration system A

Miscellaneous Electric Equipment (Plug Loads)

Absent granular measured submetered consumption data, DEER assumptions corresponding to each space were utilized as an initial approximation for plug loads in all spaces. We fine-tuned the electric plug loads in the model through a formal calibration described later in this report. These load assumptions were further refined in the electronics department (Zone 19 in Figure 1). Through a site walk-through, the electronics department was identified to contain a distinct electric plug-load density driven by an inventory of 33 large television monitors and 20 laptops on display that run continuously, 24 hours a day and 7 days a week with a total power capacity of 7.5 kW. An ENERGY STAR® power rating was assumed for each monitor and laptop, with an operating schedule that remains "on" throughout the year.

Exhaust Hoods and Fans

A complete list of all model inputs pertaining to exhaust fans used for cooking and restroom ventilation is provided in Table 5. Where capacity data were unknown, exhaust fans were auto-sized by EnergyPlus to meet modeled zone loads. The exhaust fans are scheduled to follow the operational schedules of the areas they serve. The flowrate fraction schedule for each exhaust fan is set equal to the occupancy schedule of the store.

Table 5: Exhaust Fans OpenStudio Model Inputs and Zone Assignments

Fan name	CFM	Motor HP	Area Served	Zone
EF-1	1,275	0.33	Front Restrooms	16
EF-2	500	0.167	EDC2	2
EF-3	125	0.05	Pharmacy Toilet	32
EF-4	125	0.1	Family Restroom	23
EF-5	200	0.167	Vision Center	28
EFH-1	1,425	0.75	Deli Fryer (PR)	1
EFH-2	1,075	0.75	Deli Rotisseries (PR)	1
EFH-3	900	0.5	Pizza Oven (PR)	1
EFH-4	750	0.33	Mini Rotating Rack Oven (PR)(SM)	41
EF-MCD	1,555	1	McDonalds MCD	7
EF-M1	1,200	0.25	McDonalds 2	8

AHUs 1 and 2 are required to maintain air balance for the exhausted air from EFH-1, EFH-2, EFH-3, and EFH-4, while RTU 7 and 8 balance the exhausted air from exhaust fans EF-MCD and EF-M1, respectively, to maintain negative pressure. Table 6 shows the as-built drawings for RTU 7 and RTU 8, labeled RTU-D and RTU-K, and their air-balance requirements with local exhaust fans. AHU 1 supplies air to Zones 1 and 10, while Zones 41 and 13 are served by AHU 2.

Table 6: As-Built Drawing Schedule Showing RTU 7 and RTU 8 Air Flows, Labeled RTU-D and RTU-K, and their Air-Balance Requirements with Local Exhaust Fans

Air Balance Schedule					
Unit	**Supply Air, cfm**	**Return Air, cfm**	**Outdoor Air, cfm**	**Exhaust Air, cfm**	**Pressure, cfm**
RTU-K	**3700**	**2500**	**1200**		**+1200**
RTU-D	**3700**	**2450**	**1250**		**+1250**
EF-MCD				**1555**	**-1555**
EF-1				**1200**	**-1200**
Total	**7400**	**4950**	**2450**	**2755**	**-305**
Note: Transfer air of 305 CFM supplied from Walmart Space					

Building Automation System (BAS)

The BAS is used to monitor and configure schedules for zone temperature set points and RTU settings, such as economizer dewpoint limits, CO_2 parts-per-million set points, and other parameters. A schematic of the BAS RTU controllers in the existing Walmart store is shown in Figure 6.

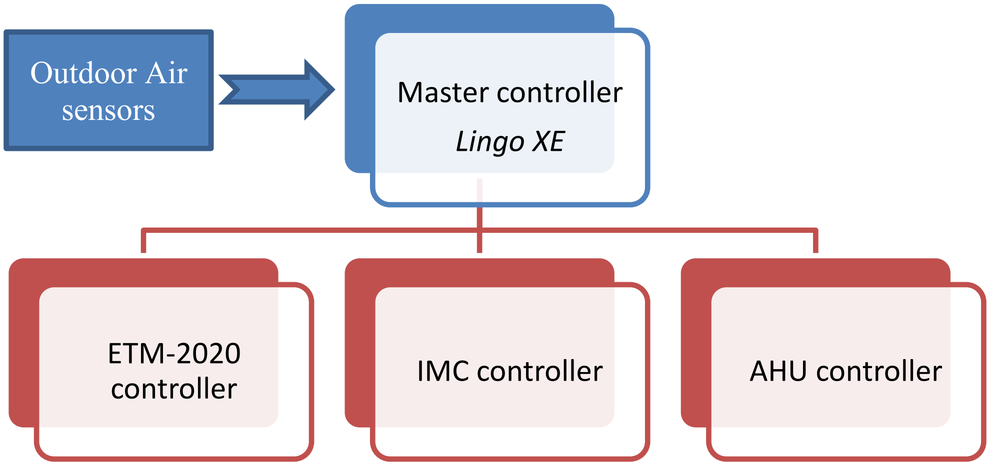

Figure 6: Schematic of the BAS controllers

The following information was collected from the controller manuals and applied to the model:

- Global Economizer lockout: Master controller – LingoXE
    - Global Enthalpy lockout at 48°F outdoor dewpoint temperature
    - Schedule applied 24/7
- Schedules, as of March 2020 – The following list shows the Novar schedule name followed by the operational schedule, followed by the RTU #
    - 18 HVAC Office: 24/7 – RTU # 4, 5, 20, 23, 24, 25, 26, 27
    - 25 HVAC Food Services: 5 a.m.–12 a.m. – RTU # 7, 8
    - 21 HVAC Optical: 8 a.m.–10 p.m. – RTU # 6, 9
    - 17 HVAC Sales Area: 24/7 – RTU # 3, 10, 11, 12, 14, 15, 17, 18, 19
    - 20 HVAC Groceries Area: 24/7 – RTU # 1, 13, 18
    - 19 HVAC Receiving: 24/7 – RTU # 2, 21, 22
    - 22 HVAC Pharmacy: 8 a.m.–10 p.m. – RTU # 16
    - AHU: 24/7
- CO_2 limit of 1,000 parts per million

Interior and Exterior Lighting

DEER assumptions were used as an initial approximation for interior lighting assignments for each space. The results were fine-tuned based on site information provided by CSE (see Appendix E), which enumerated the majority of lighting fixtures. Interior lighting power densities (LPDs) for each space in the store were calculated (see Table 7) from available schedules and modeled space areas, and the results were tuned through collected baseline M&V data submetered for lighting.

For exterior lighting, CSE identified 11 multi-lamp parking pole lights in the main parking lot area of the building, another 4 single-lamp pole lights serving the east exit road, and a series of 24 light-emitting diode (LED) lighting wall packs around the exterior of the building. These were added to the model, assuming an ENERGY STAR power rating for exterior single-lamp pole lights and exterior lighting control prescribed via schedule.

Table 7: Calculated Interior LPDs for Each Space in the Store from Lighting Schedules and Modeled Space Areas

Space Type (Model)	Space ID (Walmart)	Total Wattage	Area (ft^2)	LPD (W/ft^2)
DEER 2007-RFF-LobbyWaiting	Entrance Vestibule	1,140	1098	1.04
DEER 2007-Gro-GrocSales DEER 2007-RtL-RetailSales DEER 2007-Gro-RefWalkInCool	Main Sales Floor	99,408	103,613	1.15
	Main Sales Floor (Perimeter)	10,830		
	Main Sales Floor	3,410		
	Main Sales Floor	2,772		
	Auto Center	1,482		
	Auto Center	912		
DEER 2007-RtL-Kitchen DEER 2007-Gro-Kitchen	Deli/Bakery	2,508	6,792	0.41
	Deli/Bakery	168		
	Deli/Bakery	96		
DEER 2007-Gro-StockRoom DEER 2007-RtL-StockRoom	Stockroom	4,104	9,720	0.42
DEER 2007-Gro-OfficeGeneral DEER 2007-RtL-Break DEER 2007-Gro-CorridorStairway	Rear Office	3,648	3,670	1.53
	Rear Office	1,976		
DEER 2007-RtL-Work	Pharmacy	988	883	1.47
	Pharmacy	310		
DEER 2007-RtL-OfficeGeneral	Vision Center	472	1,539	2.44
	Vision Center	264		
	Vision Center	868		
	Vision Center	806		
	Vision Center	988		
	Vision Center	360		
DEER 2007-RFF-OfficeGeneral	Managers Office	532	807	0.94
	Managers Office	228		
DEER 2007-Gro-Restroom	Front Restroom	1,180	646	1.83
DEER 2007-RtL-Restroom	Rear Restroom	472	1,098	0.43

Service Water

Three water heaters and associated water storage tanks were identified within the plumbing schedules. Table 8 provides the model inputs and zone assignments. Unavailable capacities were auto-sized by EnergyPlus based on load assignments within the corresponding zones.

Table 8: Water Systems OpenStudio Model Inputs and Zone Assignments

Water Heater	Tank Size (Gal)	Outlet Temperature (°F)	Area Served	Zone #
1	6	140	Pharmacy	32
2	40	140	Front/Rear Toilets/Optical/Janitor	23, 16
3	100	160	Grocery	13

Schedules

The occupancy schedules were approximated using Google's "Popular Times" schedules (Figure 7), augmented with adjustments based on operating hours of the main retail space and each department within the store. The main retail space and grocery section of the store is open year-round, 7 days per week, from 6 a.m.–12 a.m. The store is only closed for business from Christmas Eve at 6 p.m. to the day after Christmas, December 26, at 6 a.m. Table 9 summarizes the operating hours used in the model for the main retail space and each department within the store.

Table 9: West Covina Walmart Hours of Operation

Space	Weekday	Saturday	Sunday
Store	6 a.m.–12 a.m.	6 a.m.–12 a.m.	6 a.m.–12 a.m.
Bakery	6 a.m.–8 p.m.	6 a.m.–8 p.m.	6 a.m.–8 p.m.
Deli	10 a.m.–8 p.m.	10 a.m.–8 p.m.	10 a.m.–8 p.m.
Auto Center	7 a.m.–7 p.m.	7 a.m.–7 p.m.	7 a.m.–6 p.m.
Pharmacy	9 a.m.–9 p.m.	9 a.m.–7 p.m.	10 a.m.–6 p.m.
Photo Center	6 a.m.–12 a.m.	6 a.m.–12 a.m.	6 a.m.–12 a.m.
Vision Center	9 a.m.–9 p.m.	9 a.m.–6 p.m.	Closed

Although the store is not open 24 hours per day, the lights and equipment in the retail, grocery, and office areas remain on during the store for night-shift employees responsible for restocking and store maintenance. Demo equipment in the electronics department is also left on continuously. The department areas (bakery, deli, auto center, pharmacy, photo, and vision center) have their lighting and electrical equipment schedules in accordance with their hours of operation. Based on the store's building management system, most HVAC systems in the store are scheduled to turn on at all times and have their occupied set-point schedules on continuously. During the store's operational hours, we leveraged Google's Popular Times schedule of the store and applied an hourly fraction value for occupant schedules for the all retail and department store space types. The office and stockroom areas were assigned a constant occupancy fraction based on the stores operational schedule. The google occupancy fractional values were also assigned to the kitchen fan hoods to model their hourly run times, assuming proportional fan usage with occupant density.

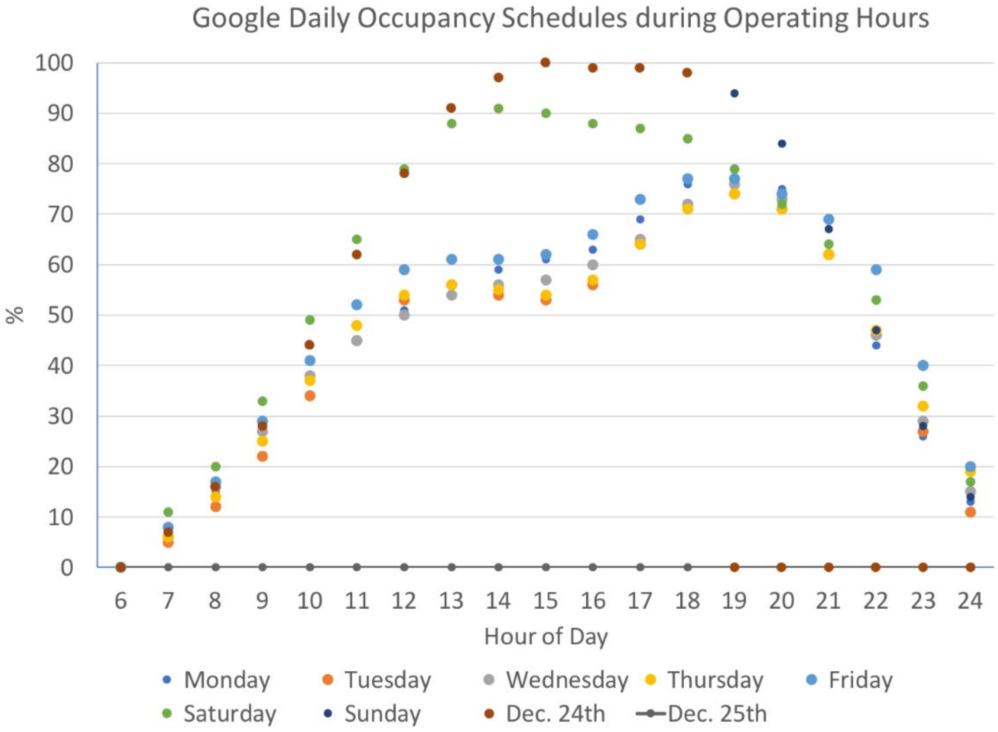

Figure 7: Google's Popular Time schedules of the West Covina Walmart store that were used to inform occupancy schedules in the baseline building energy model

Baseline Model Calibration

Overview

This section describes the overall process of calibrating the OpenStudio/EnergyPlus building energy model for the Walmart West Covina store using available monthly electric and gas consumption data. The International Performance Measurement and Verification Protocol (IPMVP) Option D was used to calibrate the model. The mechanics of using OpenStudio's PAT to execute Option D are beyond the scope of this summary and may be found in Chapter Seven of *Building Energy Modeling with OpenStudio: A Practical Guide for Students and Professionals*.[7]

Calibration Method

Calibration of the Walmart energy model was performed using monthly electric and gas consumption data along with actual meteorological year (AMY) data for that same year for

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[7] L. Brackney, A. Parker, D. Macumber, and K. Benne, *Building Energy Modeling with OpenStudio: A Practical Guide for Students and Professionals* (Springer International Publishing, 2018).

2017.[8] OpenStudio measures and parameters were used as degrees of freedom in the calibration process (Table 10). The measures were applied to all applicable spaces, surfaces, and devices in the model.

Table 10: Calibration Measures, Arguments, and Argument Ranges

Measure Name	Argument	Argument Range
Minimum Outdoor Air Flowrate Fraction	Percent of Supply Air Flowrate	5%–60%
Cooling Coils DX Percent Change *(for older RTUs – 2000 vintage)*	Percent Change for Coefficient of Performance (COP)	−60% to −20%
Cooling Coils DX Percent Change *(for newer RTUs – 2009 vintage)*	Percent Change for COP	−60% to −20%
Reduce Electric Equipment Loads by Percentage	Electric Equipment Power Reduction	±60%
Exterior Wall Thermal Percent Change	Exterior Wall Total R-Value % Change	±40%
Roof Thermal Properties Percent Change	Roof Total R-Value % Change	±40%
Water Heater Mixed Percent Change	Percent Change for Thermal Efficiency	±40%

Objective functions for the calibration included the net mean bias error (NMBE) and coefficient of variation for the root mean squared error (CVRMSE) between measured and simulated electric and gas consumption. All four objectives were treated equally for the purpose of identifying the optimal solution.

Table 11: Optimized Argument Values

Measure Name	Argument	Final Value
Minimum Outdoor Air Flowrate Fraction	Percent of Supply Air Flowrate	10%
Cooling Coils DX Percent Change *(for older RTUs – 2000 vintage)*	Percent Change for COP	−50%
Cooling Coils DX Percent Change *(for newer RTUs – 2009 vintage)*	Percent Change for COP	−40%
Reduce Electric Equipment Loads by Percentage	Electric Equipment Power Reduction	−50%
Exterior Wall Thermal Percent Change	Exterior Wall Total R-Value % Change	19.9%
Roof Thermal Properties Percent Change	Roof Total R-Value % Change	−10.1%
Water Heater Mixed Percent Change	Percent Change for Thermal Efficiency	−27.2%

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[8] AMY data were obtained from http://weather.whiteboxtechnologies.com for weather station 747043 in El Monte, California, the closest available to the Walmart site.

The measures and associated arguments chosen for calibration, outlined in Table 10, reflect variables with the highest degree of model input uncertainty. Argument value ranges were chosen based on information known and engineering intuition gained through past experiences. For example, COPs of older-vintage RTUs were allowed a higher potential decrease in performance compared with newer RTUs, therefore allowing the optimizer to properly reflect expected performance degradations. ASHRAE Guideline 14 recommends NMBE less than 5% and CVRMSE below 15% for model calibration results. Figure 8 and Figure 9 show the final optimization results for both electricity and gas consumption metrics, where ASHRAE guideline 14 is completely satisfied for electricity consumption.

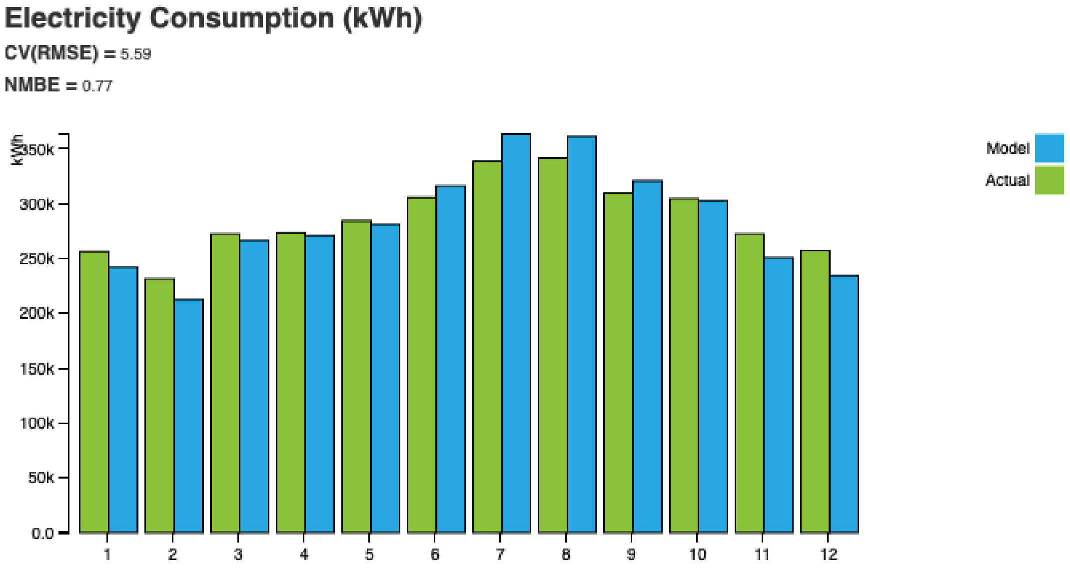

Figure 8: Monthly comparison for measured and modeled electricity consumption

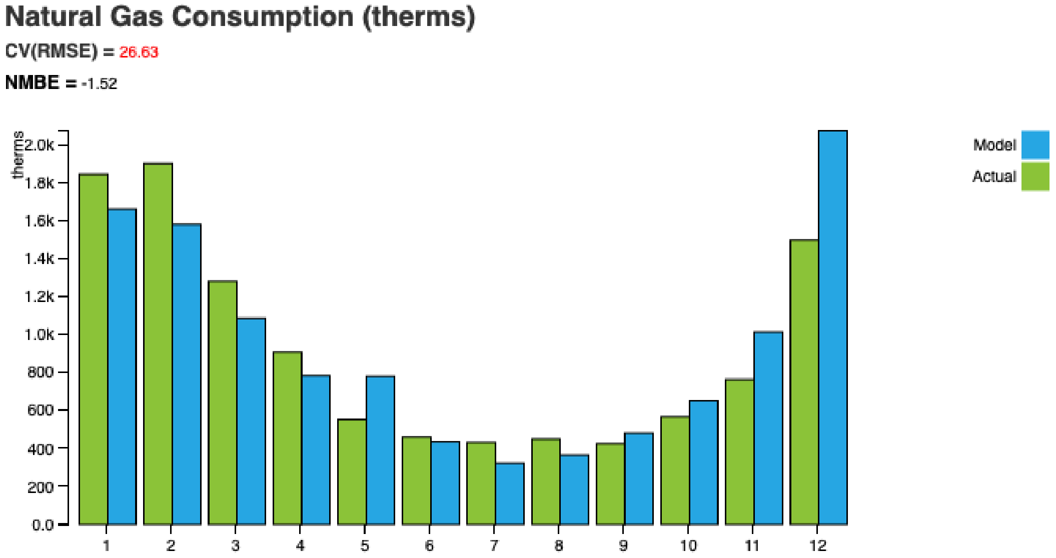

Figure 9: Monthly comparison for measured and modeled gas consumption (1 therm = 100,000 Btu)

While the modeled gas consumption does reflect general trends observed by the reported monthly utility gas use for the store, the NMBE and CVRMSE fail to remain completely within ASHRAE Guideline 14. This is due to large unexplained discrepancies observed between the spring and winter seasons with similar average outside air dry-bulb temperatures. Monthly, weather-normalized gas consumption is shown in Figure 10, where large deviations in gas consumptions (up to 60%) are observed between the months of March and November, although the average monthly dry-bulb temperature is nearly identical. Similar observations are shown in Figure 10 for the months of February and December and the months of April and May. For example, the average temperatures in November and March are both around 66°F, but the gas consumption in November is ~800 therms while the March gas consumption is about ~1,300 therms. We expect to see some gas-consumption deviations, but the change does seem to be exaggerated during the spring months (February, March, and April), which may suggest a potential retrofit that we may be unaware of, and that warrants some investigation.

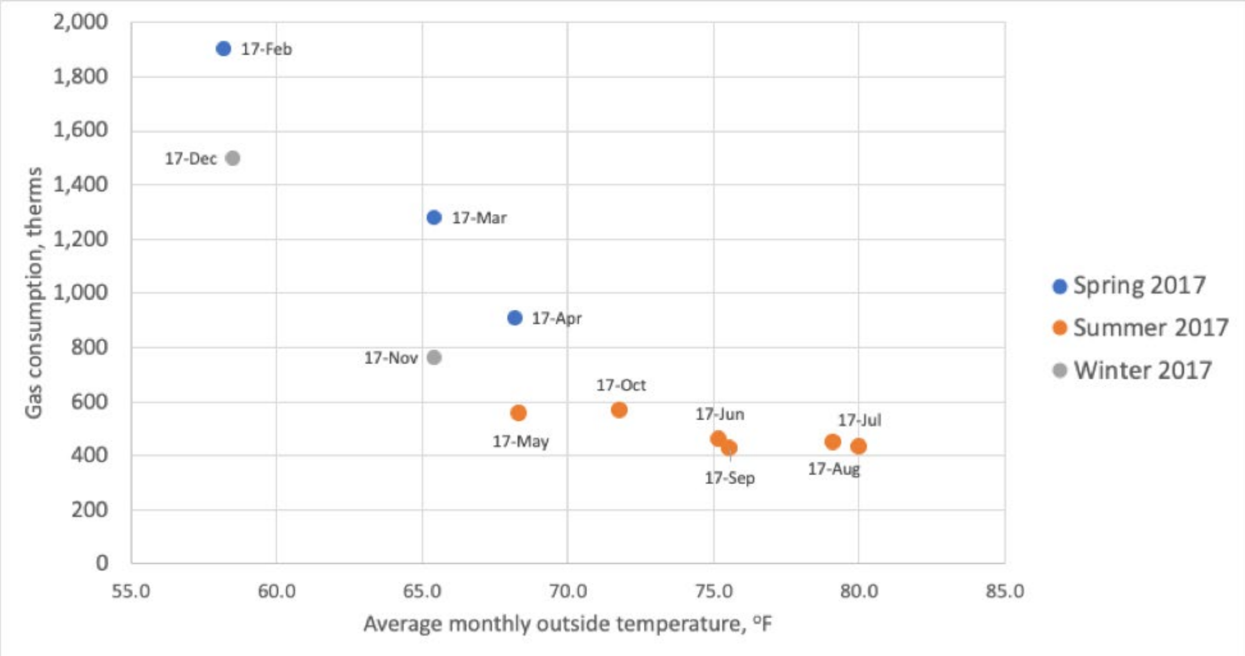

Figure 10: Monthly, weather-normalized utility gas consumption, illustrating the large deviations in gas consumption in months with similar outdoor air dry-bulb temperatures

Baseline M&V Data Benchmarking

The collected baseline M&V data include submeters for lighting, refrigeration, and HVAC (RTUs) end-uses during the month of July 2020. Due to unforeseen changes of store occupancies and operating schedules associated with COVID-19, the baseline M&V for the month of July 2020 was not used in its entirety to tune the model. While the collected baseline M&V data were only partially used, they still provided insights and opportunities for model tuning that are explained in this section of the report.

The portions of the collected baseline M&V data that remain relevant and that were used as an hourly benchmark against the baseline model include:

- Submeters associated with weather-dependent end-uses, such as:
    - *Refrigeration*: The total refrigeration electricity consumption for all racks at an hourly level was used to benchmark the model
    - *AHU 2*: Data collected for AHU 2 were used as an hourly benchmark to tune the baseline model. Data for AHU 1 were not used, as AHU 1 was faulty and non-operational during the collection period of July 2020
- *Lighting*: Store lighting is on 24/7 in the store and is time- and occupancy-independent, and was therefore used to tune the model at an hourly consumption of 99 kWh, as was demonstrated by the collected data
- *RTU 1*: Readings for RTU 1 were used to confirm a non-operational compressor, and the baseline M&V data readings for RTU 1 were of the supply fan only. Therefore, data readings for RTU 1 were used to tune the low-stage fan speed energy ratio in the model.

Figure 11 shows the actual baseline M&V data and fine-tuned model of the total hourly energy consumption for all refrigeration racks, which is weather-normalized using actual weather data for the same period of May–July 2020. The actual refrigeration consumption depicts a linear relationship with the outside air dry-bulb temperature. To tune the modeled refrigeration racks with hourly data, it was clear that an adjustment was required in the minimum condensing temperature from the original 90°F value to a lower value of 70°F. In addition, the refrigeration compressor power performance curve was tuned to closely match the trends exhibited by the collected data.

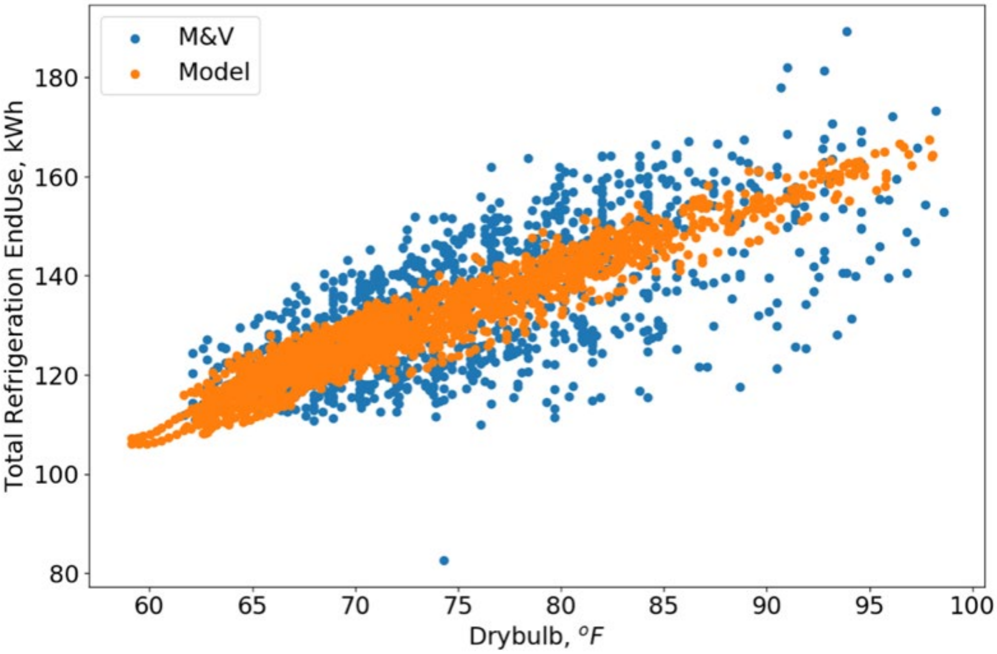

Figure 11: Actual baseline M&V data and fine-tuned model predictions of the total hourly energy consumption for all refrigeration racks, normalized by outside air dry-bulb temperature using actual weather data for the same period of May–July 2020

The compressor power performance equation is a third-degree polynomial containing two independent variables, as specified by Air-Conditioning, Heating, and Refrigeration Institute standards (AHRI 540):

$$\mathrm{P} = \mathrm{C}_1 + C_2x + C_3x^2 + C_4y + C_5y^2 + C_6xy + C_7x^3 + C_8y^3 + C_9x^2y$$

Where P is the compressor power, y is the condensing temperature, and x is the evaporating temperature. For simplicity, adjustments of the constant and linear coefficients of the power curve were tuned to closely match the baseline M&V data trends. The EnergyPlus default compressor coefficients and the calibrated values are summarized in Table 12.

Table 12: The EnergyPlus Default Refrigeration Compressor Performance Curve Coefficients and the Calibrated Values Using Baseline M&V Data for Refrigeration

Coefficient	Standards	Calibrated
C_1	4,451.46	11,000
C_4	263.553	580

A comparison of the actual and modeled weather-normalized, hourly energy consumption of AHU 2 is shown in Figure 12. The modeled energy consumption depicts similar trends and a reasonable alignment with the actual collected baseline M&V data for AHU 2. It's imperative to note that there are some uncertainties associated with AHU controls and associated settings. In addition, through a recent site survey of the store, AHU2 was reported to have short cycling issues during the M&V period. The uncertainties in AHU operations are depicted by the discrepancies shown in Figure 12 between the model and M&V data consumptions that are normalized by dry bulb temperature. While AHUs, which operate as dedicated outdoor air system (DOAS), are responsible for maintaining both temperature (76ºF zone air temperature) and humidity (52ºF space and 48ºF outdoor air dewpoint) setpoints, the AHU2 electrical consumption (fan and compressor energy) reported by M&V data and the model are better aligned when normalized by outdoor dewpoint and wet bulb temperature.

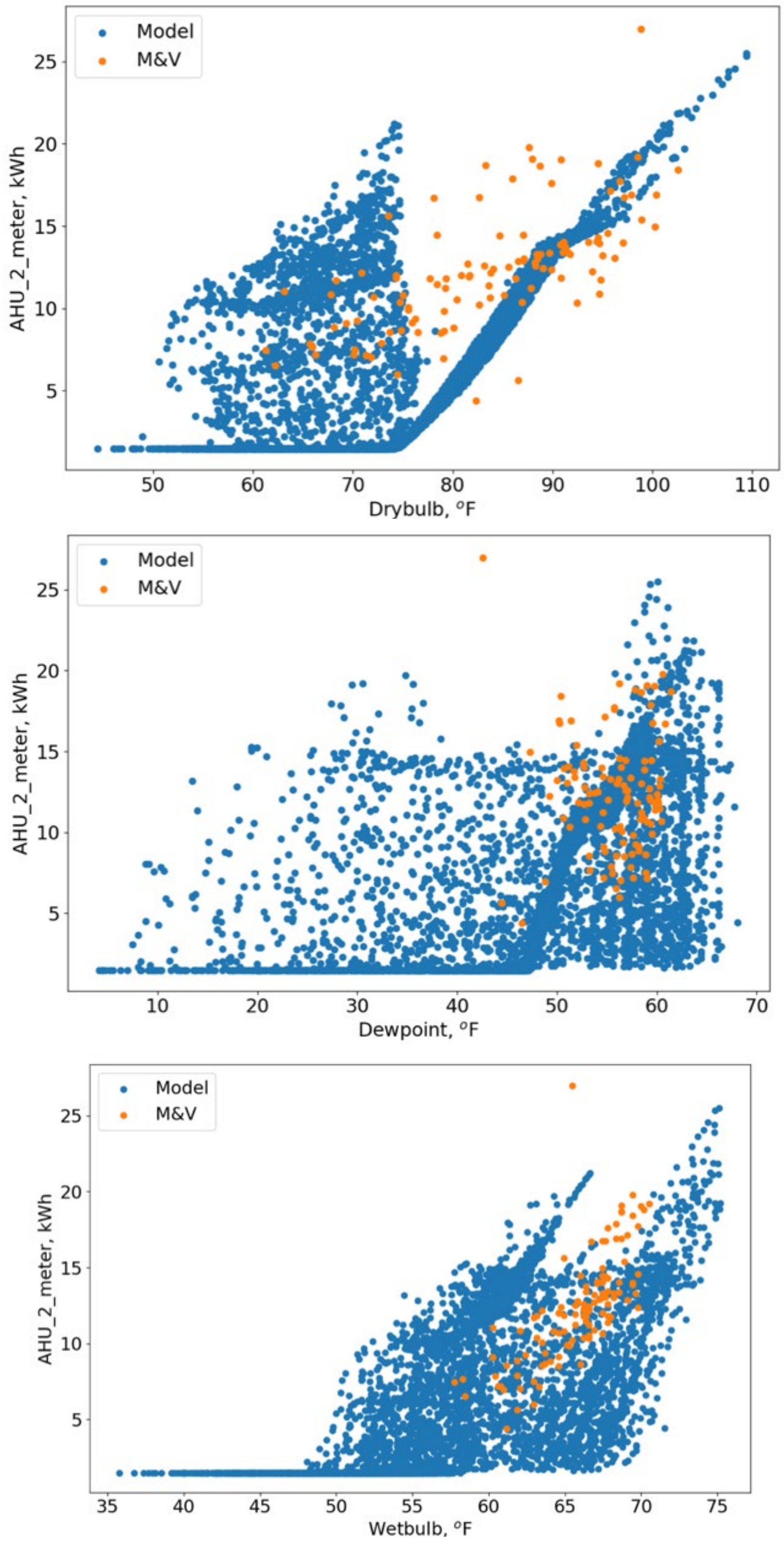

Figure 12: A comparison of the actual and modeled weather-normalized, hourly energy consumption (supply fan and compressor energy) of AHU 2

The collected baseline M&V data during July 2020 include a dedicated submeter for RTU 1, which reads an average power use in the range of 250–350 W at all times (Figure 13). This low power reading suggested a faulty and non-operational compressor, which was confirmed by the project partners. As a result, the baseline M&V data for RTU 1 reflects the variable-frequency drive supply fan power consumption only. Therefore, data readings for RTU 1 were used to tune the low-stage fan speed energy ratio in the model by comparing the average hourly demand with the design capacity.

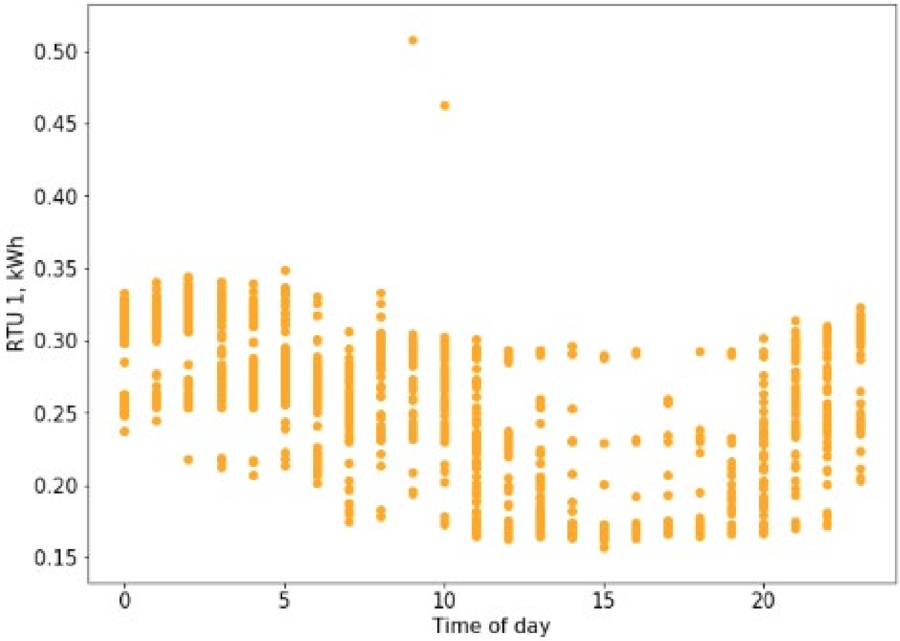

Figure 13: The collected baseline M&V data for RTU 1 normalized by weather

Calibrated Baseline Model Results

With confidence in the calibrated baseline model of the West Covina Walmart store, Figure 14 shows the model percent breakdown of energy consumption by end-use and illustrates that approximately 74% of the total site energy is consumed by three main end-uses (approximately 23% cooling, 23% indoor lighting, and 28% refrigeration). This breakdown provides an indication of those end-uses with largest energy savings potential that should be the focus of energy-efficiency activities for maximum savings (more emphasis/effort should be placed on reducing interior lighting consumption as compared with pumps or exterior lighting). The annual site energy is mostly (91%) electricity, with only 9% powered by natural gas. Furthermore, 75% of the natural gas consumption is used to heat the store. Breakdowns of the store's energy by fuel type and end-use are shown in Figure 14.

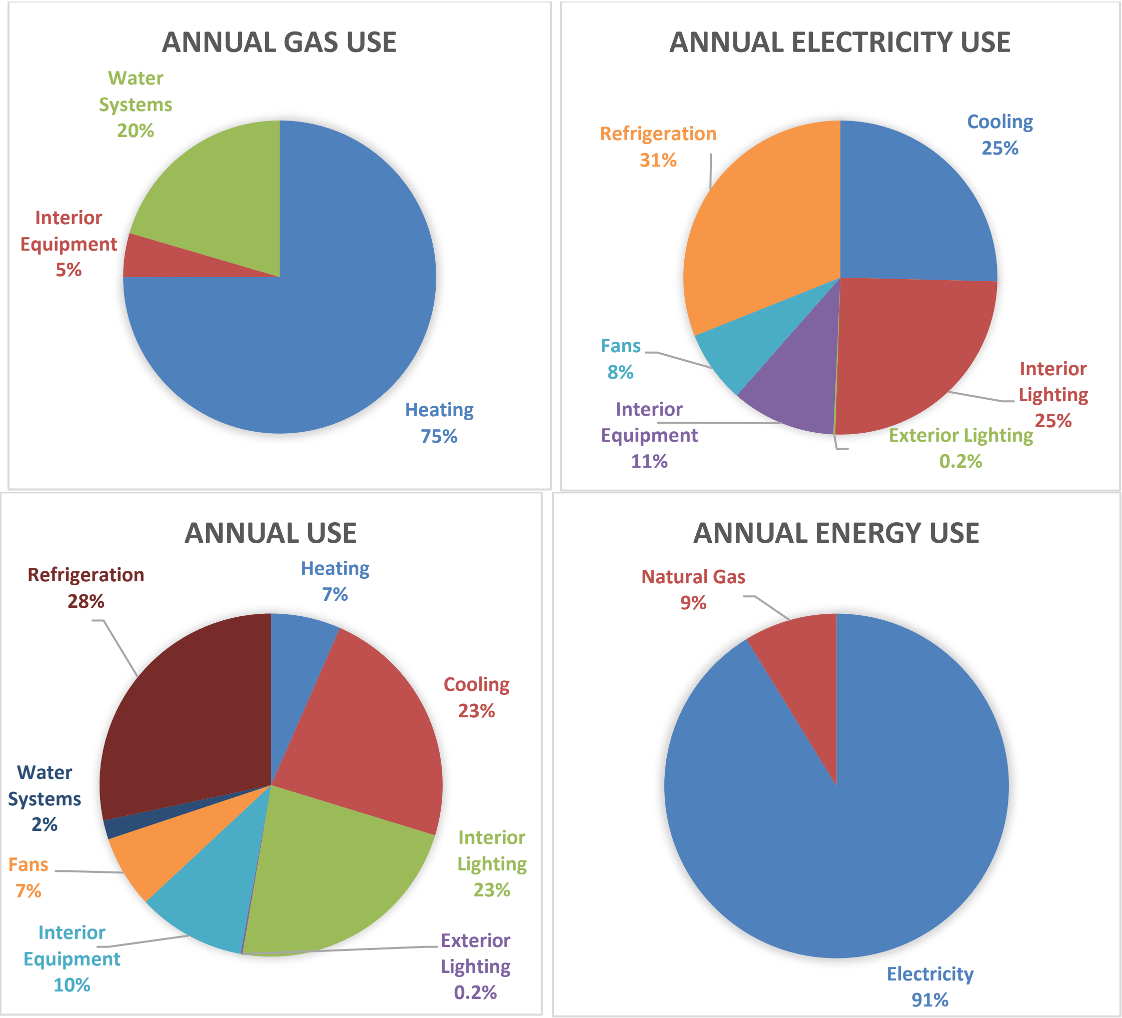

Figure 14: Calibrated baseline model results for annual energy use by fuel type and end-use

The calibrated baseline model electric monthly load profile, by end-use, is shown in Figure 15. Indoor lighting, cooling, and refrigeration are consistently the dominant end-uses throughout the year. The store's least electrical usage occurs during the month of February, while a maximum total consumption occurs during the summer month of July. Similarly, the gas monthly load profile, by end-use, is given in Figure 16. Heating remains the dominant gas consumer through the year except for the summer months. Figure 17 gives the HVAC monthly load profile illustrated by the monthly cooling and heating energy for the simulated baseline year of 2017. In addition, the outdoor air-dry bulb temperature is superimposed on the plot, illustrating its influence on the heating and cooling demands supplied by the HVAC units.

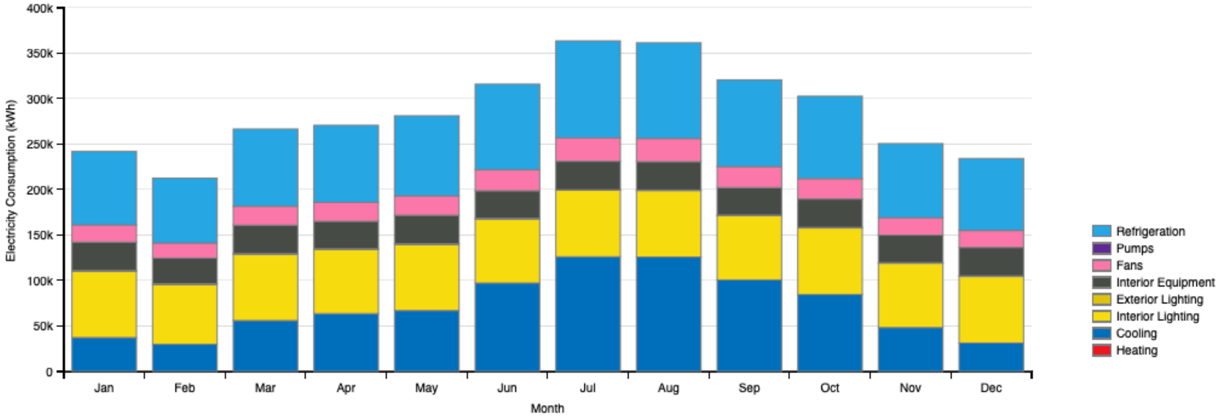

Figure 15: Calibrated baseline model – monthly electricity consumption by end-use

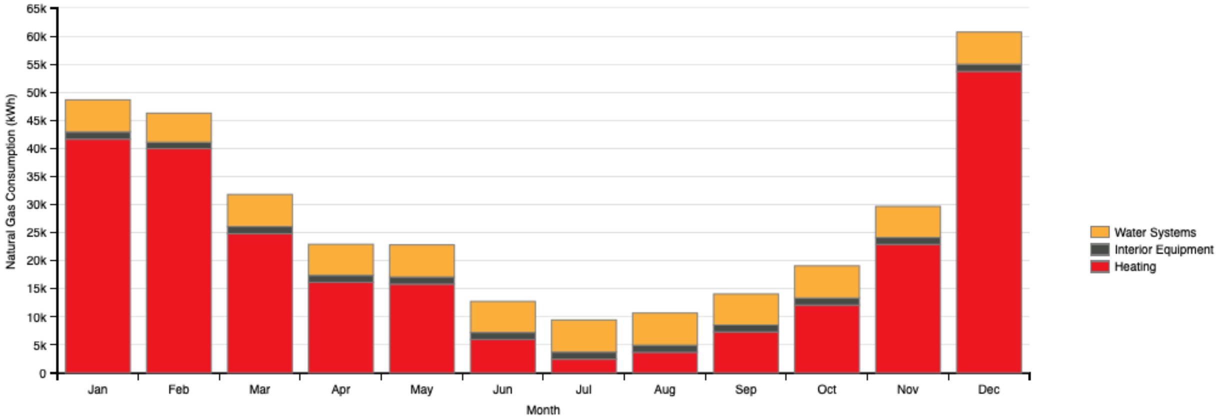

Figure 16: Calibrated baseline model – natural gas monthly consumption

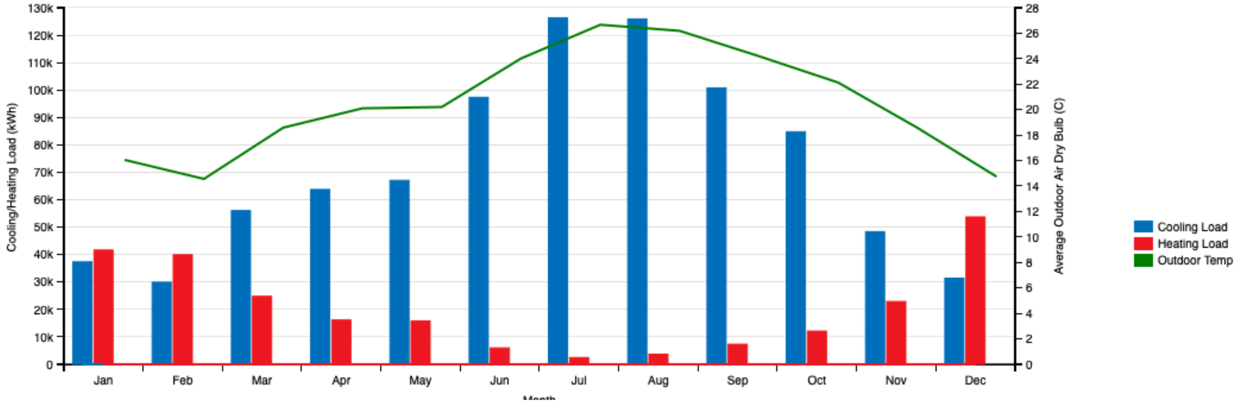

Figure 17: Calibrated baseline model – HVAC monthly load profile

Energy-Efficiency Measure Modeling

This project entails the application of several pre-commercial energy-efficiency technologies to the existing West Covina Walmart Supercenter. The primary goal of the project is to demonstrate the ability of these pre-commercial technologies to deliver electricity savings of 20% or greater. The energy-efficiency technologies will include upgrades to several systems, including (1) mechanical HVAC systems using technologies from Integrated Comfort Inc. and Software Motor

Company (SMC), (2) refrigeration systems technology from SMC, (3) centralized whole-building cloud control and monitoring technology from LocBit, and (4) DC LED lighting systems provided by a yet-to-be-determined partner.

Based on the calibrated model for the store, lighting, HVAC, and refrigeration represent dominant end-uses. This finding provides early insight into the end-uses with the largest opportunity for reducing electricity consumption in the store. To further confirm, the Morris method[9] was used to identify the relative sensitivity of LPD, electric power density (EPD), cooling COP, fan efficiencies, and envelope R-values for shaping the electricity consumption. Mu_star (μ*) shown in Figure 18 is the mean value of the absolute value of the elementary effects and represents the relative sensitivity of an output of interest to all input variables. Variables with comparatively large μ* values are very significant in shaping an output, whereas μ* equal to zero has no relationship.

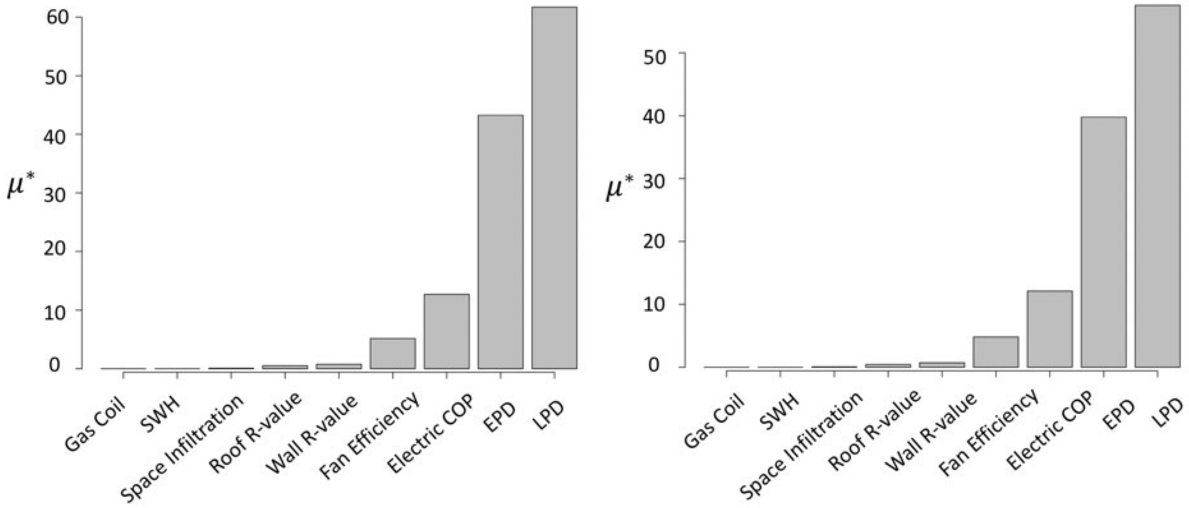

Figure 18: Electricity NMBE and CVRMSE sensitivity μ* plots

These plots indicate that lighting, electric equipment, HVAC COPs, and fan efficiencies have the largest impact in shaping the electricity consumption, while envelop measures represent a relatively weak means for reducing the overall electric consumption. These plots further confirm the correct selection of energy-efficiency technologies for maximizing the reduction in whole-building site electricity consumption for the store.

This section describes the overall process used to capture each pre-commercial technology as an OpenStudio Measure for use in PAT. The resulting analyses were used to quantify, verify, and in some cases optimize the systems to meet or exceed the project's energy-savings goals. This section summarizes recommended pathways to successfully achieve a minimum of 20% site electricity savings.

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[9] M. Morris, "Factorial Sampling Plans for Preliminary Computational Experiments," *Technometrics* 33, no. 2 (1991): 161–174.

Description of Technologies and Model Development

This section provides a brief description of each pre-commercial energy-efficiency technology and the process used to translate and develop the technology into an OpenStudio Measure for application to the calibrated baseline energy model.

DualCool

The Covina Walmart Supercenter contains 27 RTUs; each comprising a cooling coil, gas heating section, and a supply fan. A subset of the existing units (RTU # 10, 12, 15, 18, and AHU # 1 and 2) will be retrofitted with an evaporative cooling technology called DualCool, produced by Integrated Comfort Inc. DualCool precools condenser air on conventional RTUs using direct evaporative cooling without changing the humidity in the conditioned space. The system consists of an evaporative media installed at the intake of the condenser coil, a water sump below the media, a finned-tube heat exchanger installed at the outdoor intake, and a circulating pump, as shown in Figure 19.[10] Water evaporating in the media cools both itself and the air entering the condenser. Cooled water collected in the sump is pumped to the finned-tube coil, where ventilation air is sensibly cooled by the water.

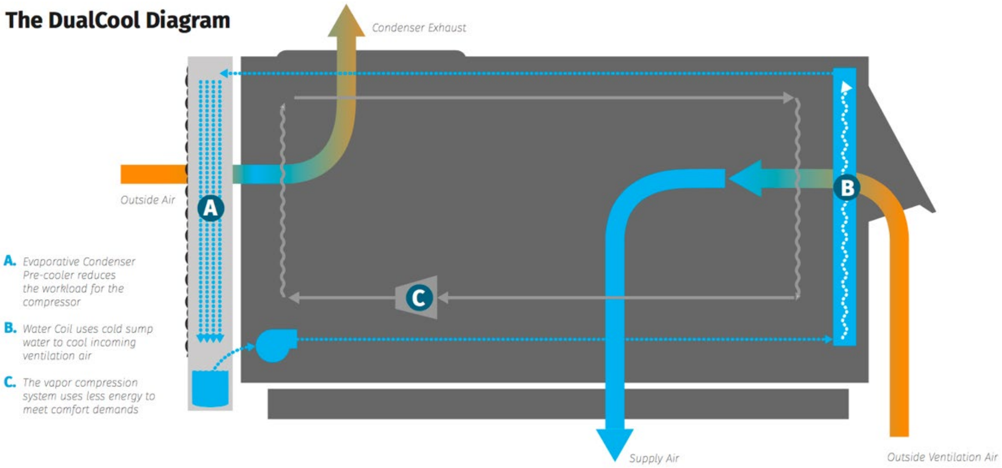

Figure 19: DualCool diagram (courtesy of DualCool)

DualCool saves energy and precool supply air in two ways, hence its name. First, cooling-coil energy requirements are reduced by precooling the outdoor air delivered to the RTU cooling coil. Second, the air temperature seen by the RTU condenser coil is reduced, decreasing the refrigerant pressure and the work that must be done by the compressor. A more-detailed schematic of the DualCool system is shown in Figure 20.[9]

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[10] http://www.icidualcool.com/documents/

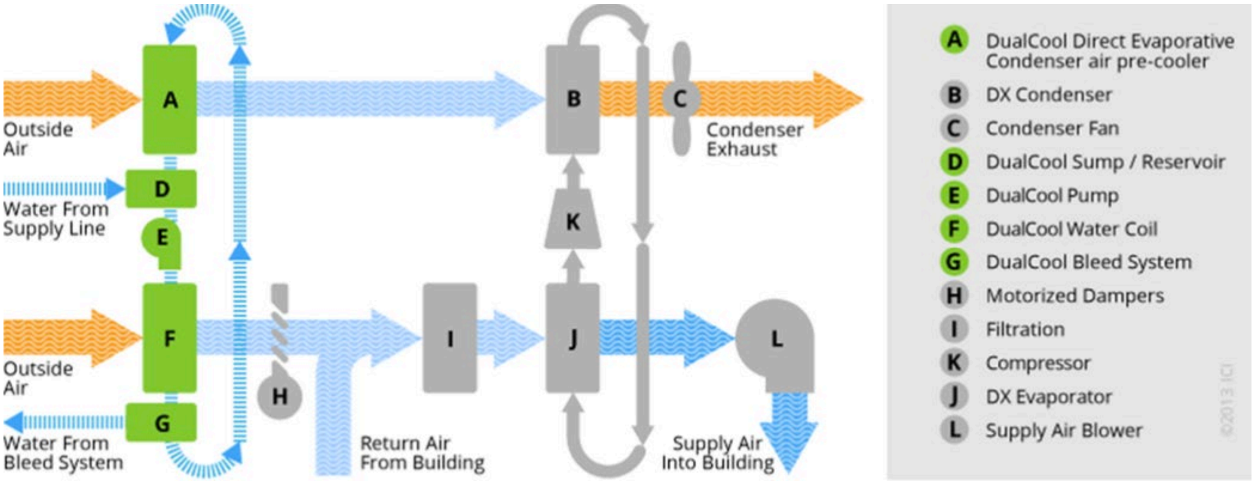

Figure 20: DualCool detailed schematic (courtesy of DualCool)

The OpenStudio Measure for DualCool is composed of two elements: (1) addition of the model objects for each component in the DualCool system and (2) definition of the control strategy used to manage DualCool retrofit units and any other surrounding units that interact with DualCool retrofitted units. Key OpenStudio Measure parameters provided by DualCool indicate an average direct evaporative effectiveness of 80% for precooling coil-condenser air and an indirect evaporative effectiveness of 70% for precooling the outside air. These effectiveness values were critical for developing and modeling the modified inlet air conditions for both the condenser and cooling coil.

The direct evaporative condenser air precooler is modeled by modifying the inlet ambient air conditions to the condenser. In a perfectly efficient evaporative process, the leaving dry-bulb temperature would equal the entering wet-bulb temperature. For less-efficient processes, the leaving dry-bulb temperature is modeled according to the following equation:

$$T_{db} = T_{wb} + (1 - \epsilon)(T_{db} - T_{wb})$$

where T_{db} is the outside air dry-bulb temperature, T_{wb} is the outside air wet-bulb temperature, and ϵ is the average direct evaporative effectiveness value provided by DualCool.

EnergyPlus includes a special indirect evaporative cooling model object[11] used to simulate this aspect of the DualCool system, modifying the air inlet temperature based on the average direct evaporative effectiveness parameter. This EnergyPlus object is frequently used for hybrid cooling applications and includes performance curves for pump power and water consumption calculations.

A local temperature controller on each RTU is used to enable/disable DualCool mode. DualCool mode is enabled for RTUs when the outside air dry-bulb temperature exceeds 70°F and the outside air dewpoint temperature remains below 48°F for RTU. DualCool mode is enabled for

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[11] https://bigladdersoftware.com/epx/docs/8-8/engineering-reference/evaporative-coolers.html#indirect-evaporative-cooler-special-research-model

AHUs when the outside air dry-bulb temperature exceeds 70°F, regardless of the dewpoint temperature. While enabled, the DualCool-enabled RTUs interact with their grouped AHUs per the sequence of operations outlined by the matrix in Table 13. Two sets of RTUs and an AHU are grouped, where AHU 1 interacts with RTUs 10 and 12, while AHU 2 interacts with RTUs 15 and 18. The control sequence in Table 13 is outlined for AHU 1 and RTU 10 and 12, and a similar sequence is applied for AHU 2 and RTUs 15 and 18.

Table 13: DualCool Control Sequence

AHU 1 and RTUs 10 and 12 Sequence of Operations						
#	**RTU Mode**	**AHU 1 Mode**	**Outdoor Condition**	**AHU-1**	**RTU-10**	**RTU-12**
1A	Both RTUs 10 and 12 have no cooling request	Ventilation Mode	>70°F dry-bulb (DB) and <48°F dewpoint (DP)	DualCool	Off due to auto fan	Off due to auto fan
1B	Either RTU 10 or RTU 12 has cooling request			Off	DualCool (Shift ventilation requirements to RTUs 10 and 12)	DualCool (Shift ventilation requirements to RTUs 10 and 12)
1C	When RTUs 10 and 12 have a cooling request		>70°F DB and DP >48°F	DualCool	CoilCool	CoilCool
2A	Has cooling request	Has Cooling request	>70°F DB and <48°F DP	DualCool	DualCool (no modification to damper position)	DualCool (no modification to damper position)
2B	Has cooling request		>70°F DB and DP >48°F	DualCool	CoilCool	CoilCool

To model the controls in Table 13 for DualCool in OpenStudio, we used the Energy Management System object[12] in EnergyPlus to sense the weather conditions at each timestep of the simulation and assign the appropriate modes of operation corresponding to each scenario in Table 13. EnergyPlus allows users to set up customized controls by reading and modifying input and output variables during the simulation. The custom logic is applied at each simulation timestep. The general OpenStudio measure controls architecture used to model DualCool operations is illustrated in Figure 21.

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[12] https://bigladdersoftware.com/epx/docs/8-0/input-output-reference/page-046.html

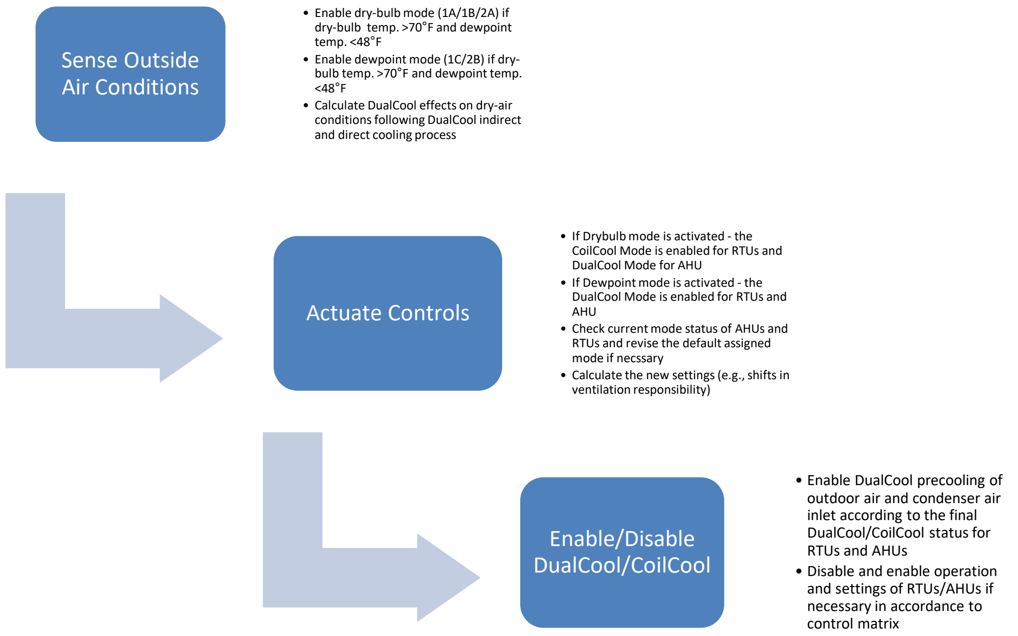

Figure 21: A schematic of the OpenStudio measure controls architecture used to model DualCool operations and controls

Software Motor Company (SMC) [13]

RTUs throughout the store will be retrofitted with software commutated high rotor pole switched-reluctance motors and smart control systems produced by SMC to further reduce energy usage. SMC motors have demonstrated significant improvements over standard induction motors in torque, power density, efficiency, versatility, and cost. Refrigeration condenser fans in the store will also be retrofitted SMC motors.

The existing fan motor efficiencies in the store and the performance data for SMC motor efficiencies are provided in Table 14. The OpenStudio Measure representing SMC retrofits consists of changes to motor efficiency parameters in the affected model objects and their performance curve to achieve part-load usage with fan efficiencies at 30% and motor efficiencies at 88%. Performance data provided by SMC were used to derive their motor performance curves for RTUs and AHUs, shown in Figure 22.

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[13] At the time of writing, SMC rebranded to Turntide Technologies

Table 14: Existing Fan Motor Efficiencies in the Store and the Performance Data for SMC Motor Efficiencies

		Baseline Model			Proposed Model *(SMC Motor)*	
RTU Model	**Fan Motor (W)**	**Fan Efficiency**	**Motor Efficiency**	**Pressure Rise (Pa)**	**Minimum Flowrate (Part load ratio)**	**Motor Efficiency**
LGB036	373	0.19	0.56	100	0.45	0.88
SGA036	1,119	0.26	0.76	511	0.45	0.88
SCA036	1,119	0.26	0.76	511	0.45	0.88
LGB060	1,119	0.19	0.56	226	0.45	0.88
SGA060	1,119	0.26	0.76	371	0.45	0.88
LGB120	1,492	0.19	0.56	163	0.45	0.88
SGA120	2,238	0.28	0.82	357	0.45	0.88
LGB240	3,730	0.28	0.81	311	0.3	0.88
RN025	1,492	0.29	0.86	264	0.3	0.88

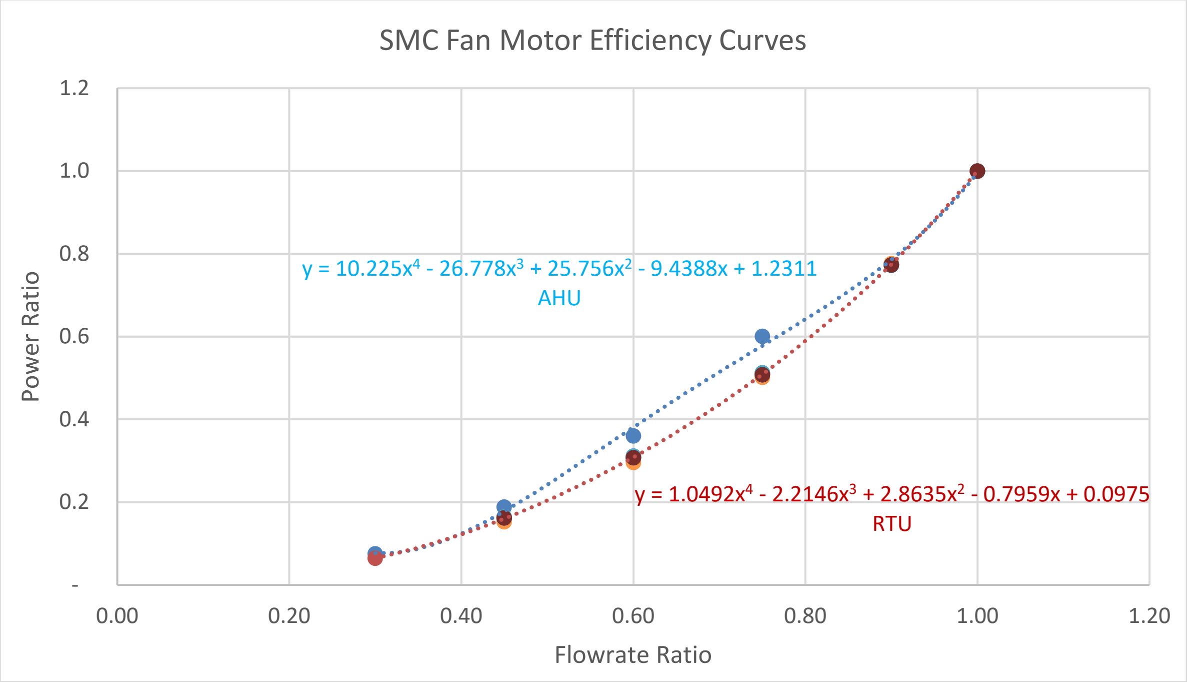


Figure 22: SMC fan motor performance curves used in the models for AHUs and RTUs

SMC motors allow the RTU to be converted from constant volume to variable air volume, with minimum flowrate requirement derived from the manufacturer documents and design documents. Variable-air-volume control was applied, per Figure 23, without reheat.[14]

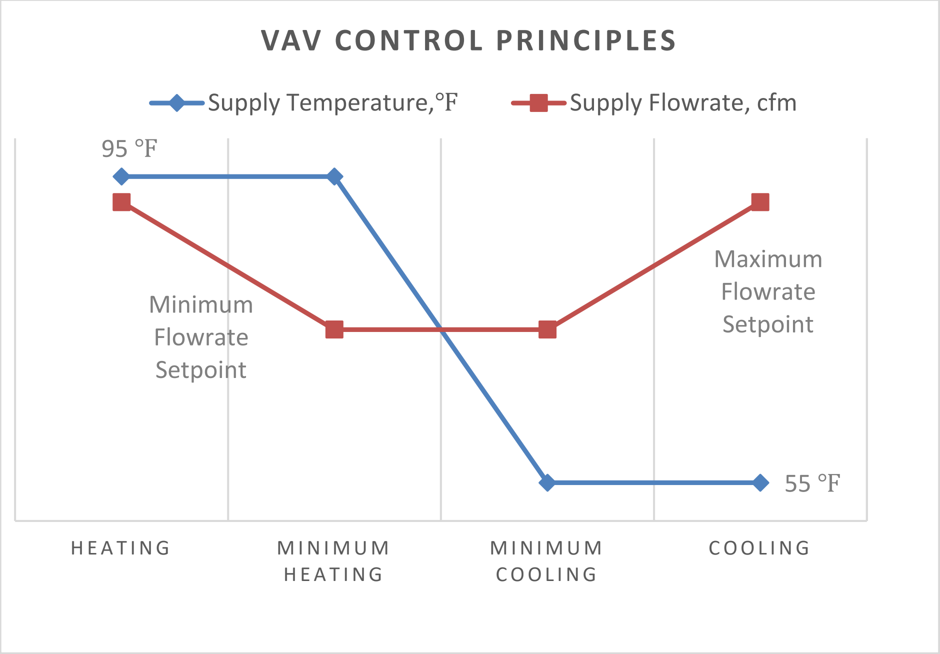


Figure 23: SMC variable-air-volume control

The zone cooling and heating temperature set points and their differential set points are configurable at both local and central interfaces. Those set points are trigger points for cooling and heating stages and economizer-integrated cooling operations. The thermostat set points applied to each stage of cooling and heating stages are summarized in Table 15.

Table 15: Thermostat Set Points Applied to Each Stage of Cooling and Heating

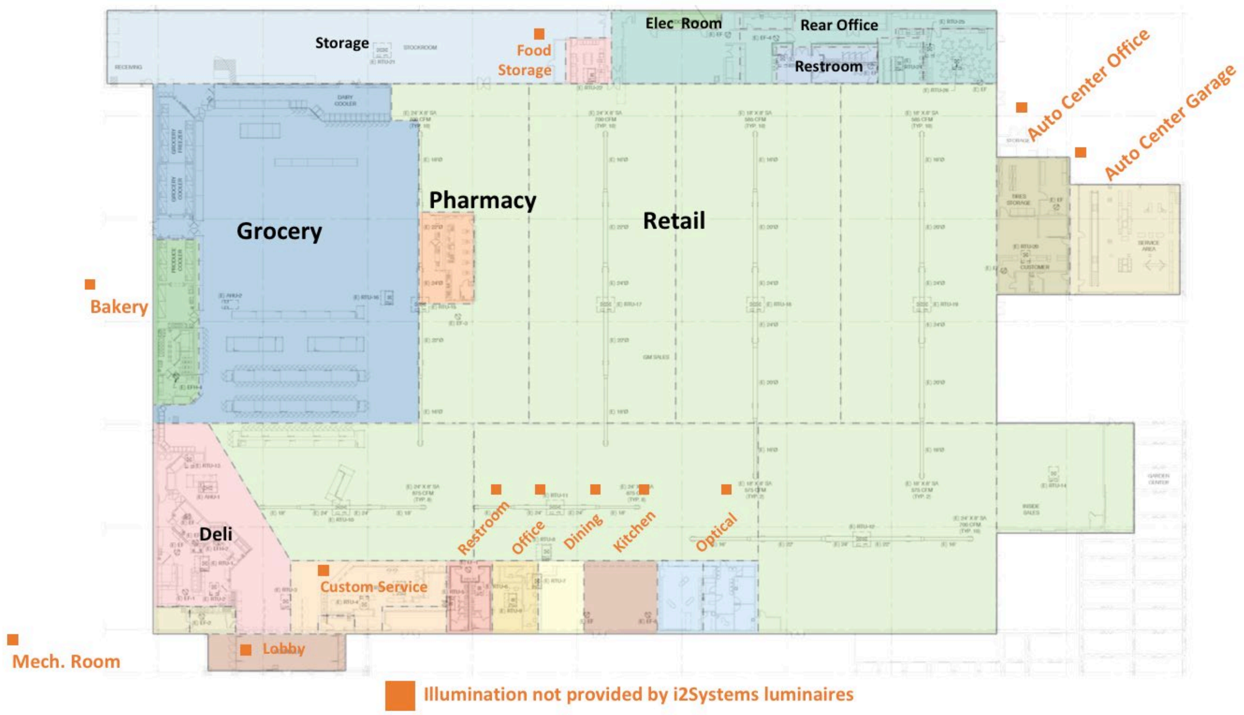
Mode	Integrated Economizer Mode	Cooling Mode	Heating Mode
Cooling Stage 1	Turn On 76°F Turn Off 75°F	Turn On 76°F Turn Off 75°F	
Cooling Stage 2	Turn On 76.5°F Turn Off 75.5°F	Turn On 77°F Turn Off 76°F	
Heating Stage 1			Turn On 67°F Turn Off 68°F
Heating Stage 2			Turn On 66°F Turn Off 67°F

---

[14] See Appendix H for a description of the current proposed design in the McDonalds Kitchen and a potential alternative design scenario

LED Lighting System

The lighting system retrofit involves replacing existing fluorescent fixtures with LED equivalent units. The garden space (Zone 14) will be retrofitted with DC LED lighting systems, that achieve additional efficiencies by avoiding AC-to-DC conversion, and the remaining fixtures will be replaced with AC LED systems. The I2S LED lighting system will be retrofitted throughout the store, except for spaces outlined in Figure 24. The post-retrofit LPD values per space in the store listed in Figure 24 were provided by I2S and were used in the model to estimate the savings impact associated with I2S and the interactive effects their lighting system may have with other end-uses in the store.



Function	Grocery	Retail	Deli	Storage	Rear Office	Electrical Room	Rest Room	Pharmacy (High ceiling lights)
Estimated Existing LPD, W/ft^2	**1.24**	**1.24**	**0.41**	**0.46**	**1.31**	**0.77**	**0.47**	**1.24**
Post-Retrofit LPD, W/ft^2	**0.67**	**0.71**	**0.44**	**0.31**	**0.33**	**0.67**	**0.47**	**0.44**

Figure 24: Spaces in the West Covina Walmart store planned for being retrofitted with the I2S lighting system, and their associated LPDs per space

Energy Optimization System

All energy-efficiency upgrades and technologies will be coordinated by LocBits's cloud-based integration platform, accessible through authorized local, remote, and mobile devices. The LocBit system will monitor all connected building systems to detect energy waste, equipment malfunctions, and other operation problems using fault detection and diagnostics algorithms and performance visualizations. In addition, the following four permanent energy-efficiency strategies provided through LocBit controls were identified and modeled:

1. Reduced plug loads, by turning off TV displays (nominal load of 7.5 kW) in the electronics department (Zone 19) during non-business hours (12–6 a.m.)
2. Dim lighting (60% reduction in lumens) during non-business hours in the I2S retrofitted spaces outlined in Figure 24
3. Adjust zone temperature set points by +2°F for cooling and −2°F for heating during non-business hours in perimeter spaces not retrofitted by I2S system, shown in Figure 24
4. Scheduled walk-in refrigeration set-point temperature reset by +2°F during non-business hours.

Proposed Model Results and Discussion

Including all energy-efficiency technologies (DualCool, SMC, DC lighting, and LocBit) into one package produces the results shown in Figure 25 (left). The results were produced by running all energy-efficiency measures simultaneously and includes interactive effects. These results represent one particular pathway to achieving the 20% site electricity savings target. As depicted, 2.8% of site electricity may be saved by retrofitting both AHUs and four of the 20-ton RTUs with DualCool. SMC retrofits of all RTUs, AHUs, and refrigeration condenser fans is expected to result in 6.1% savings. Through LocBit, shutting off the electronic department display monitors and laptops during unoccupied hours, lighting controls, and zone and refrigeration temperature set points are expected to contribute 1.9% in site electricity savings. Upgrading to DC LED lighting through I2S could save as much as 10.9% in site electricity. The total savings associated with these retrofits falls slightly above the 20% reduction goal.

While a cost effectiveness analysis of the measures is not in the scope of this work, the associated annual electricity cost savings associated with the measures were estimated using the store tariffs[15] and presented in Figure 25 (right). PV generation was included in the model for the cost savings estimate, with an estimated 60% of the rooftop being covered with PV[16], at 18% solar cell efficiency and 98% inverter efficiency. Although the model was not calibrated with solar PV generation, this approximation provides a reasonable cost savings estimate given the available data.

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[15] Southern California Edison (CSE) rate TOU-8-B: https://www.sce.com/regulatory/tariff-books/rates-pricing-choices/business-rates

[16] Based on the site characterization report

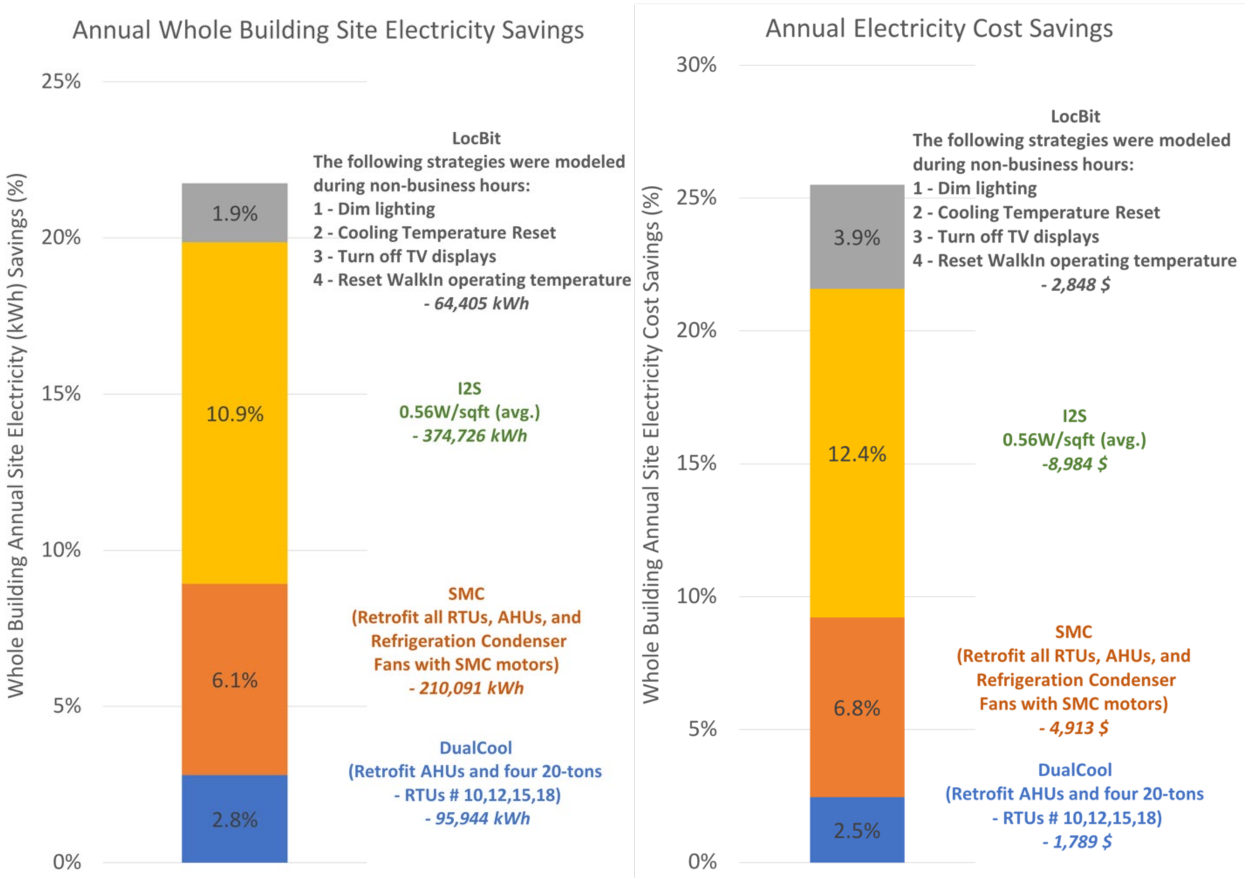


Figure 25: Pathway to Walmart's 20% whole-building site electricity savings (left), and associated annual electricity cost savings (right)

While the baseline and proposed building energy models do not include building pressurization, the impacts of building pressurization on the proposed model are provided in Appendix F.

Conclusion

A calibrated baseline building energy model of the West Covina Walmart store was developed using DOE's OpenStudio modeling platform. Calibration of the Walmart energy model was performed using monthly electric and gas consumption data along with actual meteorological year (AMY) data for the baseline year of February 2017–January 2018. Hourly baseline M&V data for the month of July 2020 were used to further tune the baseline model for refrigeration and lighting end-uses. Furthermore, the collected baseline M&V data were useful for benchmarking two HVAC units in the baseline model. OpenStudio was also leveraged for modeling the energy-efficiency measures. Through DualCool's innovative HVAC evaporative cooling technology and SMC's commutated high rotor pole switched-reluctance motors, HVAC/R retrofits have the opportunity for approximately 8.9% in site electricity savings. Lighting system replacement of fluorescent with DC LED systems, through I2S, has the opportunity for approximately 10.9% in annual site electricity savings. Furthermore, LocBit's integrated building-level control and supervisory system can offer an additional 1.9% in permanent electricity savings through optimized controls and set-point adjustments. The modeled integrated suite of technologies does attain the project's target of 20% in whole-building site electricity savings. However, while the modeling efforts and savings estimates provided in this report are useful in understanding the relative impacts of each energy-efficiency technology, actual operations of the store maybe different than those specified in as-built drawings and schedules. As a result, actual normalized metered energy consumption savings calculations may differ from modeling predictions.

Appendix A. Identified Thermostats in the Store

Identification and mapping of thermostat locations to HVAC systems, through a detailed site walkthrough, confirmed the model zoning. The identified thermostats and their locations within the store are shown in Figure A-1.

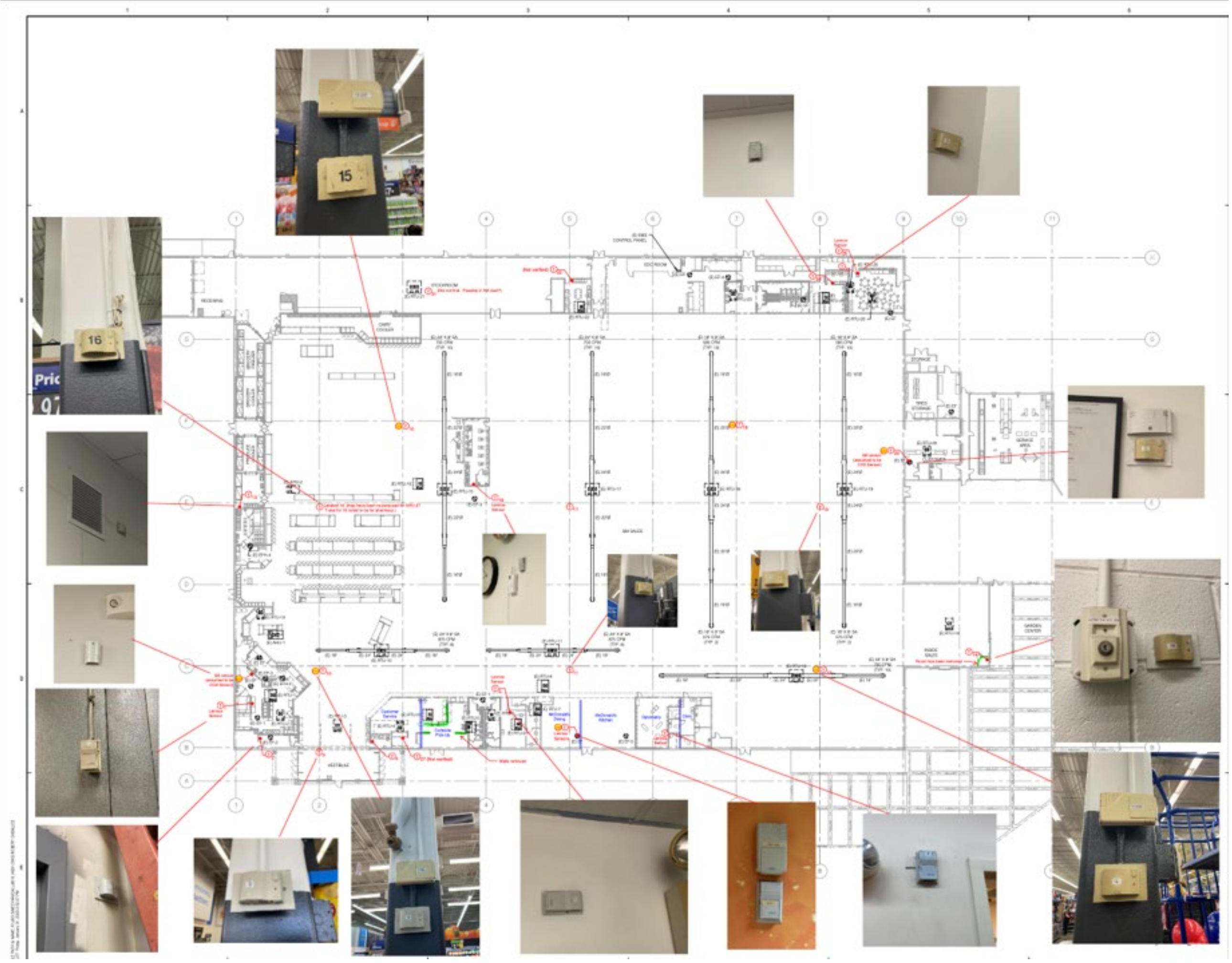
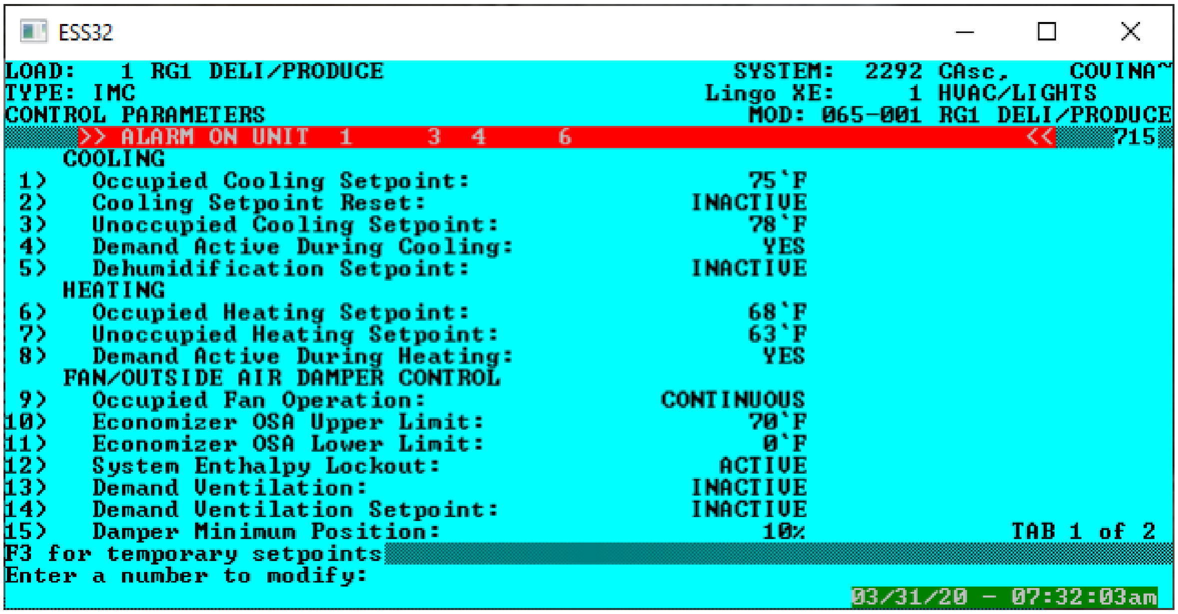


Figure A-1: Identified thermostats and their locations within the store

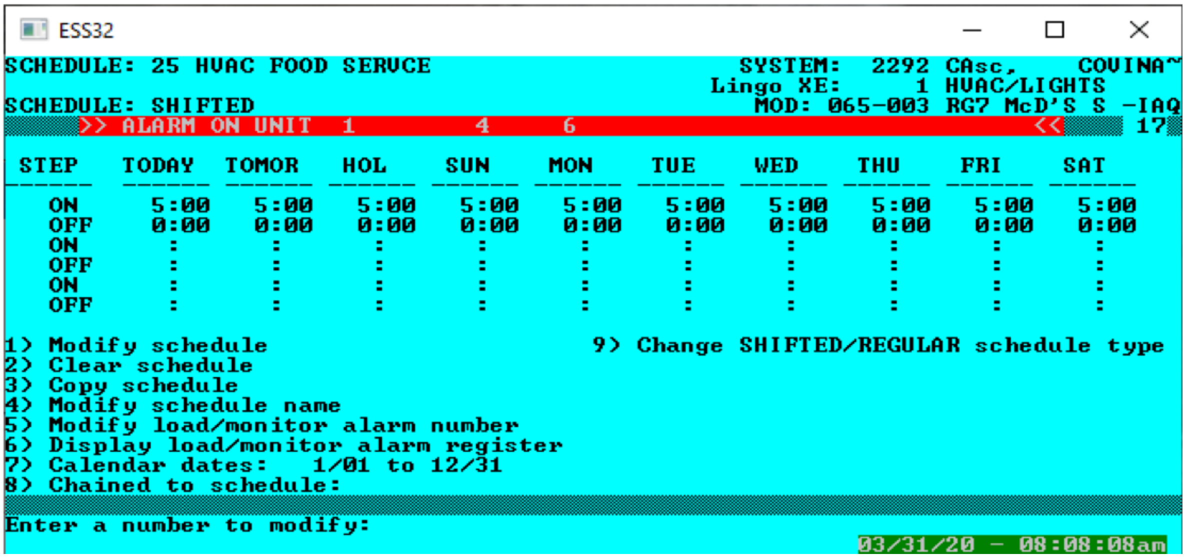
Appendix B. RTU Set Points and Schedules from Novar Interface

Each RTU in the store has its own occupied and unoccupied set points and schedules. A sample Novar user interface screenshot showing the occupied and unoccupied thermostat set points for RTU #1 is shown in Figure B-1, and a sample showing the occupied and unoccupied schedule modes for RTU #7 from a Novar user interface screenshot is shown in Figure B-2.



```
LOAD:    1 RG1 DELI/PRODUCE                       SYSTEM:  2292 CAsc,    COVINA~
TYPE: IMC                                       Lingo XE:      1 HVAC/LIGHTS
CONTROL PARAMETERS                                  MOD: 065-001 RG1 DELI/PRODUCE
     >> ALARM ON UNIT  1     3  4     6                                <<    715
    COOLING
 1)   Occupied Cooling Setpoint:                      75`F
 2)   Cooling Setpoint Reset:                     INACTIVE
 3)   Unoccupied Cooling Setpoint:                    78`F
 4)   Demand Active During Cooling:                    YES
 5)   Dehumidification Setpoint:                  INACTIVE
    HEATING
 6)   Occupied Heating Setpoint:                      68`F
 7)   Unoccupied Heating Setpoint:                    63`F
 8)   Demand Active During Heating:                    YES
    FAN/OUTSIDE AIR DAMPER CONTROL
 9)   Occupied Fan Operation:                   CONTINUOUS
10)   Economizer OSA Upper Limit:                     70`F
11)   Economizer OSA Lower Limit:                      0`F
12)   System Enthalpy Lockout:                      ACTIVE
13)   Demand Ventilation:                         INACTIVE
14)   Demand Ventilation Setpoint:                INACTIVE
15)   Damper Minimum Position:                         10%               TAB 1 of 2
F3 for temporary setpoints
Enter a number to modify:
                                                           03/31/20 - 07:32:03am
```

Figure B-1: A sample Novar user interface screenshot showing the occupied and unoccupied thermostat set points for RTU #1



```
SCHEDULE: 25 HVAC FOOD SERVCE                     SYSTEM:  2292 CAsc,    COVINA~
                                                Lingo XE:      1 HVAC/LIGHTS
SCHEDULE: SHIFTED                                   MOD: 065-003 RG7 McD'S S -IAQ
     >> ALARM ON UNIT  1        4     6                                <<      17

 STEP    TODAY   TOMOR   HOL     SUN     MON     TUE     WED     THU     FRI     SAT
------  ------  ------  ------  ------  ------  ------  ------  ------  ------  ------
   ON     5:00    5:00    5:00    5:00    5:00    5:00    5:00    5:00    5:00    5:00
   OFF    0:00    0:00    0:00    0:00    0:00    0:00    0:00    0:00    0:00    0:00
   ON      :       :       :       :       :       :       :       :       :       :
   OFF     :       :       :       :       :       :       :       :       :       :
   ON      :       :       :       :       :       :       :       :       :       :
   OFF     :       :       :       :       :       :       :       :       :       :

1) Modify schedule                        9) Change SHIFTED/REGULAR schedule type
2) Clear schedule
3) Copy schedule
4) Modify schedule name
5) Modify load/monitor alarm number
6) Display load/monitor alarm register
7) Calendar dates:   1/01 to 12/31
8) Chained to schedule:

Enter a number to modify:
                                                           03/31/20 - 08:08:08am
```

Figure B-2: The occupied and unoccupied schedule modes for RTU #7 from a Novar user interface screenshot

Appendix C. RTU Cooling Coil Performance Curves

DX Coil Performance Curves – Second Stage

Total cooling capacity modifier curve (function of temperature)	
Curve:Biquadratic	
DX Total Cooling Cap f(T)	*!- Name*
0.523570956	*!- Coefficient1 Constant*
0.034777768	*!- Coefficient2 x*
	*!- Coefficient3 x**2*
-0.001915358	*!- Coefficient4 y*
-1.08E-04	*!- Coefficient5 y**2*
	*!- Coefficient6 x*y*
9.277777778	*!- Minimum Value of x*
26.83333333	*!- Maximum Value of x*
15.55555556	*!- Minimum Value of y*
44.72222222	*!- Maximum Value of y*

Energy input ratio (EIR) modifier curve (function of temperature)	
Curve:Biquadratic	
DX Energy Input Ratio f(T)	*!- Name*
0.984651981	*!- Coefficient1 Constant*
-0.042854153	*!- Coefficient2 x*
0.001356227	*!- Coefficient3 x**2*
0.00993408	*!- Coefficient4 y*
0.000639785	*!- Coefficient5 y**2*
-0.001169011	*!- Coefficient6 x*y*
9.277777778	*!- Minimum Value of x*
26.83333333	*!- Maximum Value of x*
15.55555556	*!- Minimum Value of y*
44.72222222	*!- Maximum Value of y*

Total cooling capacity modifier curve (function of flow fraction)	
Curve:Quadratic	
DX Total Cooling Cap f(m)	*!- Name*
0.768518891	*!- Coefficient1 Constant*
	!- Coefficient2 x
0.231481109	*!- Coefficient3 x**2*
0.810810811	*!- Minimum Value of x*
1.162162162	*!- Maximum Value of x*

Energy input ratio (EIR) modifier curve (function of flow fraction)	
Curve:Quadratic	
DX Energy Input Ratio f(m)	*!- Name*
1.191672073	*!- Coefficient1 Constant*
-0.191672073	*!- Coefficient2 x*
	*!- Coefficient3 x**2*
0.810810811	*!- Minimum Value of x*
1.162162162	*!- Maximum Value of x*

DX Coil Performance Curves – First Stage

Total cooling capacity modifier curve (function of temperature)	
Curve:Biquadratic	
DX Total Cooling Cap f(T)	*!- Name*
0.413577204	*!- Coefficient1 Constant*
0.031052138	*!- Coefficient2 x*
	*!- Coefficient3 x**2*
0.006951738	*!- Coefficient4 y*
-2.13E-04	*!- Coefficient5 y**2*
	*!- Coefficient6 x*y*
9.277777778	*!- Minimum Value of x*
26.83333333	*!- Maximum Value of x*
15.55555556	*!- Minimum Value of y*
44.72222222	*!- Maximum Value of y*

Energy input ratio (EIR) modifier curve (function of temperature)	
Curve:Biquadratic	
DX Energy Input Ratio f(T)	*!- Name*
1.138853977	*!- Coefficient1 Constant*
-0.045180225	*!- Coefficient2 x*
0.001429841	*!- Coefficient3 x**2*
0.006043717	*!- Coefficient4 y*
0.000674511	*!- Coefficient5 y**2*
-0.001232463	*!- Coefficient6 x*y*
9.277777778	*!- Minimum Value of x*
26.83333333	*!- Maximum Value of x*
15.55555556	*!- Minimum Value of y*
44.72222222	*!- Maximum Value of y*

Total cooling capacity modifier curve (function of flow fraction)	
Curve:Quadratic	
DX Total Cooling Cap f(m)	*!- Name*
0.694380888	*!- Coefficient1 Constant*
0.305619112	*!- Coefficient2 x*
	*!- Coefficient3 x**2*
0.810810811	*!- Minimum Value of x*
1.162162162	*!- Maximum Value of x*

Energy input ratio (EIR) modifier curve (function of flow fraction)	
Curve:Quadratic	
DX Energy Input Ratio f(m)	*!- Name*
1.254671013	*!- Coefficient1 Constant*
-0.254671013	*!- Coefficient2 x*
	*!- Coefficient3 x**2*
0.810810811	*!- Minimum Value of x*
1.162162162	*!- Maximum Value of x*

Appendix D. AHU Coil Performance Curves

	First Stage		**Second Stage**	
	Cap F(T)	**EIR F(T)**	**Cap F(T)**	**EIR F(T)**
Const	0.82308177	0.5973496	0.70496838	0.6922437
x	-0.0009786	-0.024678	0.01362349	-0.0116132
x2	1.06E-03	0.00056624	9.52E-04	0.0001939
y	-0.0003838	0.02944003	0.00146218	0.00887879
y2	-2.06E-04	0.0003836	-6.78E-05	0.00047034
XY	-8.12E-07	-0.0011303	-4.33E-04	-0.0006306
	First Stage		**Second Stage**	
	Cap F(F)	**EIR F(F)**	**Cap F(F)**	**EIR F(F)**
Const	0.86521211	1.46772661	0.7683433	0.28110218
FF	-0.0475082	-0.6784196	0.31436372	1.04081729
FF2	1.82E-01	0.210693	-0.082707	-0.3681345

Appendix E. Lighting Schedule

Area	Space ID	Fixture Description	kW per Fixture	Fixture Qty	Total Wattage
Interior	Entrance Vestibule	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	10	1,140
Interior	Main Sales Floor	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	872	99,408
Interior	Main Sales Floor (Perimeter)	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	95	10,830
Interior	Main Sales Floor	(Typ 53B) Recessed Wall Wash F54T5HO 1-Lamp	62	55	3,410
Interior	Main Sales Floor	(Typ 57A) Bussway Spotlight 70T6 1-Lamp	77	36	2,772
Interior	Deli/Bakery	(Typ 10) 2'x4' Recessed Troffer F32T8 2-Lamp	76	33	2,508
Interior	Deli/Bakery	(Typ 58A) Ceiling Glass Pendant Kit LED	84	2	168
Interior	Deli/Bakery	(Typ 68A) Recessed Downlight 12W LED	12	8	96
Interior	Stockroom	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	36	4,104
Interior	Rear Office	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	32	3,648
Interior	Rear Office	(Typ 10) 2'x4' Recessed Troffer F32T8 2-Lamp	76	26	1,976
Interior	Auto Center	(Typ TBD) 2'x4' Recessed Troffer F32T8 4-Lamp	114	13	1,482
Interior	Auto Center	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	8	912
Interior	Pharmacy	(Typ 10) 2'x4' Recessed Troffer F32T8 2-Lamp	76	13	988
Interior	Pharmacy	(Typ 53B) Recessed Wall Wash F54T5HO 1-Lamp	62	5	310
Interior	Vision Center	(Typ 52) 2'x2' Parabolic Troffer FB32T8 2-Lamp	59	8	472
Interior	Vision Center	(Typ 51) Suspended Glass Pendant C18W	22	12	264
Interior	Vision Center	(Typ 53) Recessed Wall Wash F54T5HO 1-Lamp	62	14	868
Interior	Vision Center	(Typ 54) Shelf Mounted Uplight F54T5HO 1-Lamp	62	13	806
Interior	Vision Center	(Typ 10) 2'x4' Recessed Troffer F32T8 2-Lamp	76	13	988
Interior	Vision Center	(Typ 24) Recessed Downlight 90PAR38	90	4	360
Interior	Managers Office	(Typ 10) 2'x4' Recessed Troffer F32T8 2-Lamp	76	7	532
Interior	Managers Office	(Typ 1) 1'x8' Surface F32T8 4-Lamp	114	2	228
Interior	Front Restroom	(Typ 8) 1'x4' Recessed Troffer F32T8 2-Lamp	59	20	1,180
Interior	Rear Restroom	(Typ 8) 1'x4' Recessed Troffer F32T8 2-Lamp	59	8	472
Total				**1,345**	**139,922**

Appendix F. Impacts of Building Pressurization on Electricity Savings

Building Pressurization Modeling Approach:

The baseline model assumes a balance between the RTU exhaust air flow and the outdoor air flow, meaning the RTUs have a neutral pressurization condition. The minimum outdoor air fraction for all RTUs except RTUs 1, 7, and 8 is assumed at 0.1, per information gathered from building management system interface screenshots and design documents. Table F-1 summarizes the total flowrates for each exhaust fan in the baseline building model, where the total exhausted air in the store sums to 9,130 CFM. In order to maintain building pressurization at a supply-to-exhaust air flow ratio of 1.25, the required supply air flow is calculated in Table F-2. The pharmacy RTU airflows and the McDonalds Kitchen RTU airflows were not adjusted due to their existing operational requirements.

Table F-1: Existing Exhaust Fan Schedules, Areas Served, and Flowrates

Exhaust Fan Name	CFM	Area Served	Schedule
EF-1	1,275	Front Restrooms	24/7
EF-2	500	EDC2	24/7
EF-3	125	Pharmacy Toilet	6 a.m.–midnight
EF-4	125	Family Restroom	24/7
EF-5	200	Vision Center	6 a.m.–midnight
EFH-1	1,425	Deli Fryer (PR)	6 a.m.–midnight
EFH-2	1,075	Deli Rotisseries (PR)	6 a.m.–midnight
EFH-3	900	Pizza Oven (PR)	6 a.m.–midnight
EFH-4	750	Mini Rotating Rack Oven (PR)(SM)	6 a.m.–midnight
EF-MCD	1,200	McDonalds MCD	6 a.m.–midnight
EF-M1	1,555	McDonalds 2	6 a.m.–midnight
Total	**9,130**		

Table F-3 shows the calculation made to arrive at the necessary outdoor air flow requirement to maintain a positive pressure at a ratio of 1.25. The table demonstrates that 2,375 CFM surplus outside air is needed for building pressurization from midnight to 6 a.m., and therefore the existing operation of one AHU is enough to satisfy this requirement. During business hours (6 a.m. to midnight), one particular pathway to satisfy building pressurization is to set up a continuous fan mode with a dedicated flowrate for ventilation and a minimum fraction flowrate for SMC supply fan motors (0.3/0.45). The outdoor air dampers for all RTUs listed in Table F-3 should be configured to ensure a cumulative flowrate of at least 2,100 CFM (more than 2,013 CFM)

Table F-2: Calculations of the Required Supply Air Flow to Maintain Building Pressurization at a Supply-to-Exhaust Air Flow Ratio of 1.25

Period	Exhaust Air		Outdoor Air Intake		Building Pressure Requirement (1.25)		Recommendation
	Source	Airflow, CFM	Source	Airflow, CFM	Required airflow, CFM	Airflow shortage, CFM	
6 a.m.–midnight	All exhaust fan	9,130	AHU 1, 2 RTU 7, 8	9,400	11,413 (9,130*1.25)	−2,013	Add surplus CFM as shown in Table 3
midnight –6 a.m.	EF-1/2/4	1,900	AHU 1, 2	7,000	2,375 (1,900*1.25)	+4,625	Turn off AHU1 during 0-6AM

Table F-3: RTU Outdoor Air Flowrate Contributions that Arrive at the Necessary Outdoor Air Flow Requirement for Building Pressurization

		Baseline		Building pressurization		
RTU	Supply Air (CFM)	Minimum Outdoor Air (CFM)	Exhaust (CFM)	Minimum Outdoor Air (CFM)	Exhaust (CFM)	Outdoor Air Surplus (Outdoor Air – Exhaust) (CFM)
2	2,000	200	200	270	200	70
4	2,000	200	200	270	200	70
13	2,000	200	200	270	200	70
20	2,000	200	200	270	200	70
23	2,000	200	200	270	200	70
25	2,000	200	200	270	200	70
26	2,000	200	200	270	200	70
3	3,700	370	370	499.5	370	129.5
14	3,700	370	370	499.5	370	129.5
11	7,000	700	700	945	700	245
17	7,000	700	700	945	700	245
19	7,000	700	700	945	700	245
21	7,000	700	700	945	700	245
9	1,200	120	120	162	120	42
22	1,200	120	120	162	120	42
24	1,200	120	120	162	120	42
27	1,200	120	120	162	120	42
5	1,650	165	165	222.75	165	57.75
1	3,700	1,200	1,200	1,620	1,200	420
Total		**7,540**	**7,540**	**7,540**	**6,785**	**2,375**

Building Pressurization Savings Impact

Table F-4 shows the difference in the total annual whole-building site energy use between the non-pressurized proposed model and the proposed model with pressurization. The results indicate a 1.1% decrease in total cumulative electricity savings considering all energy-efficiency measures and their interactive effects.

Table F-4: Difference in the Total Annual Whole-Building Site Energy Use Between the Non-Pressurized Proposed Model and the Proposed Model with Pressurization

Options	Whole-Building Annual Electricity Consumption (kWh)	% Difference in Whole-Building Electricity Savings
Non-pressurized Proposed Model	2,681,348	
Proposed Model with Pressurization	2,718,240	−1.1

Appendix G. Impacts of Alternate DualCool Sequence of Operation

The application of DualCool reduces the sensible load of any outside air introduced by RTUs or AHUs retrofitted by the system. In doing so, the compressor loading is reduced, and the suction temperature is increased, assuming a constant volume system. In scenarios where dehumidification of the outside air is requested, the compressors are controlled to maintain the suction (saturation) temperature setpoint, which results in non-optimal energy savings. Figure 29 demonstrates the relationship between unloading the compressor and its effects on the required saturated suction temperatures. As a result, an investigation of a scenario is presented here where AHUs are placed in CoilCool mode during dehumidification requests, which may lead to more efficient dehumidification operations.

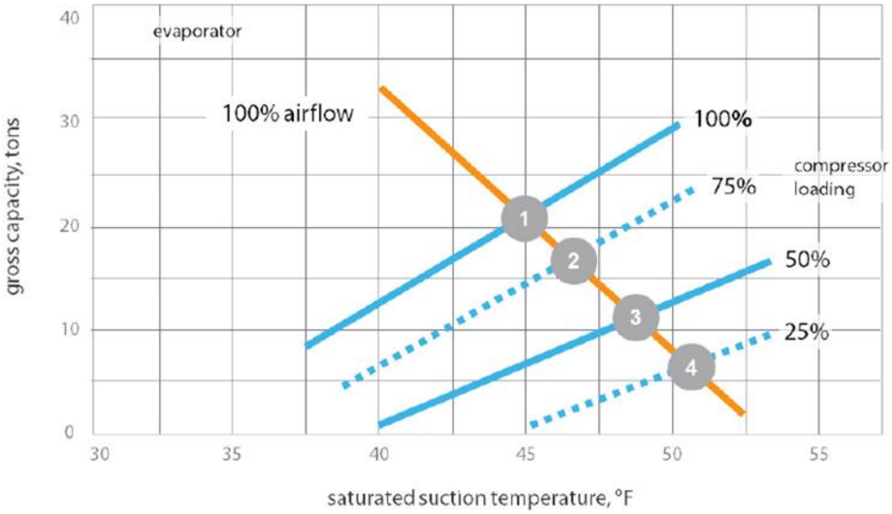


Figure G-1: Demonstrates the relationship between unloading the compressor and its effects on the required saturated suction temperatures[17]

The original control sequence (outlined in Table 13) also suggests a shift in ventilation responsibility from AHUs to RTUs while DualCool mode is enabled and evaporative precooling is taking place. While this approach is generally favorable, in this particular Walmart store the RTUs are older (2000) than AHUs (2009), with potentially significantly degraded efficiencies. In addition, the manufacturer's EER for the AHUs is higher than the RTUs. Therefore, in some circumstances, the benefits of evaporatively precooling the shifted ventilation air may not outweigh the lower efficiencies of the existing RTUs. Therefore, the alternate scenarios presented here also remove this shift in ventilation from AHUs to RTUs.

Furthermore, based on calculations performed in Appendix F (Table F-2), AHU 1 can be turned off during non-business hours due to decreased ventilation requirements, even in the scenario of

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[17] Trane Engineers Newsletter volume 48–4 - Understanding the Selection of Direct Expansion (DX) Evaporator Coils

a pressurized building. Therefore, the scenarios outlined here also include turning off AHU 1 during non-business hours.

Table G-1 shows three scenarios modeled with varying DualCool integrations, and their associated whole-building electricity savings.

Table G-1: Alternative DualCool Integration Scenarios and their Associated Whole-Building Electricity Savings

Scenario	Integration Control	AHU mode in scenarios 1C/2B of DualCool sequence (Table 13)	DualCool Whole-Building Electricity Savings (%)
Original Operation	Shift ventilation to RTU when applicable per the original control sequence (Table 13)	DualCool	2.8
Alternative 1	Turn off AHU 1 from 12 a.m. to 6 a.m.	DualCool	3.4
Alternative 2	Turn off AHU 1 from 12 a.m. to 6 a.m.	CoilCool	3.2

Moreover, the outdoor air conditions that enable DualCool mode (>70°F dry-bulb and <48°F dewpoint) can be revised to attain more electricity savings that optimize DualCool operations. To demonstrate, the histogram in Figure G-1 shows the number of hours, annually, in each outside air dewpoint temperature range (when conditions are above 70°F dry bulb) and indicates that a missed opportunity occurs in the range of 56°F–59°F dewpoint, where a high number of potential DualCool operating hours are missed.

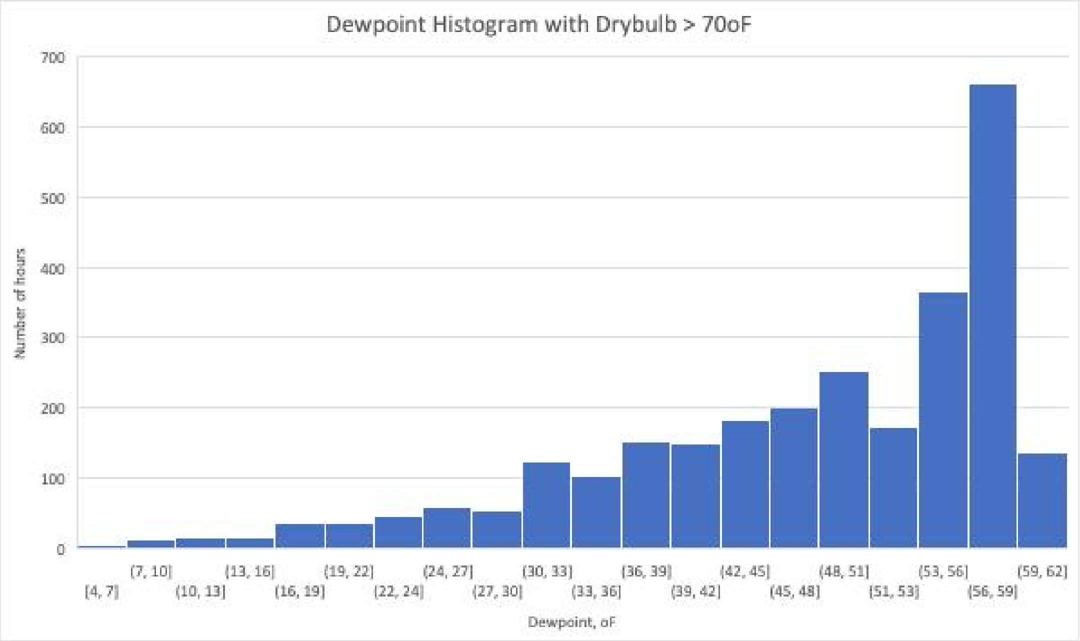


Figure G-2: Number of hours, annually, in each outside air dewpoint temperature range

The electricity savings impact associated with increasing the dewpoint temperature lockout conditions that enable DualCool mode are demonstrated in Figure G-2. The percent savings shown in Figure G-2 are of the whole-building annual site electricity savings associated with DualCool retrofits only, and each curve reflects the scenarios outlined in Table G-1.

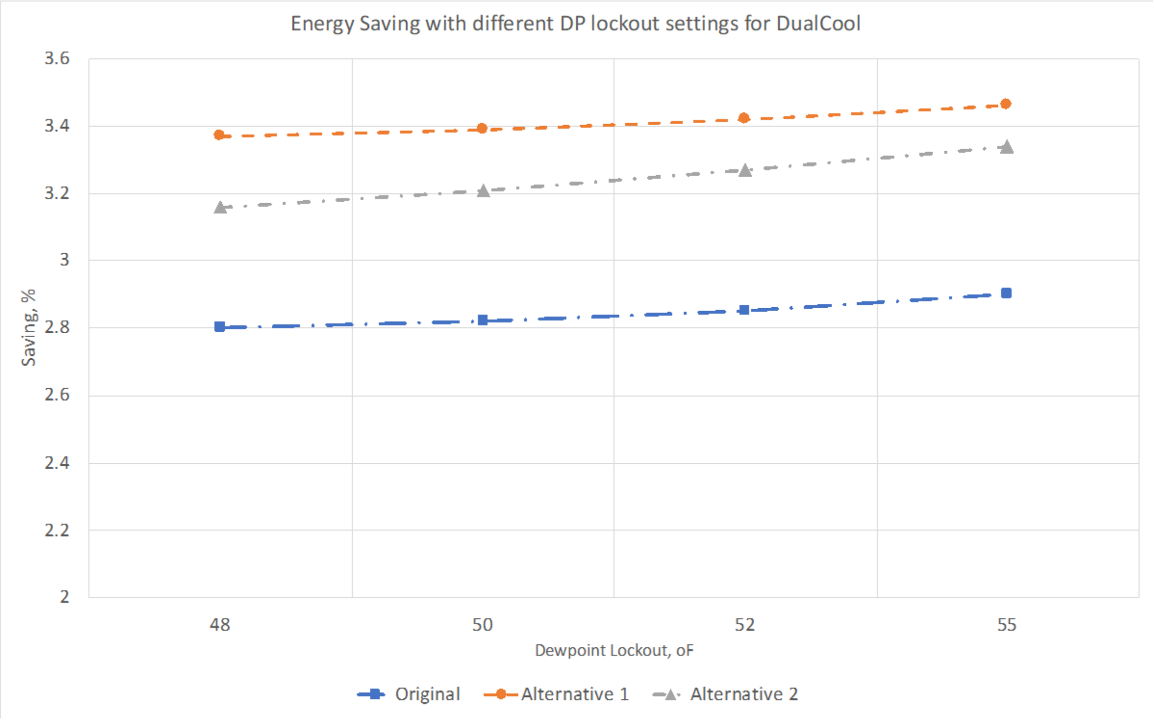


Figure G-3: Electricity savings impact associated with increasing the dewpoint temperature lockout conditions that enable DualCool

Moreover, the implications of increasing the DualCool dewpoint temperature lockouts on the mean dry-bulb and wet-bulb temperatures across all zones, annually, in the store are demonstrated in Figure G-3. Note that the alternate scenarios proposed in Table G-1 result in lower mean dewpoint temperatures, which is a result of more-effective dehumidification operations.

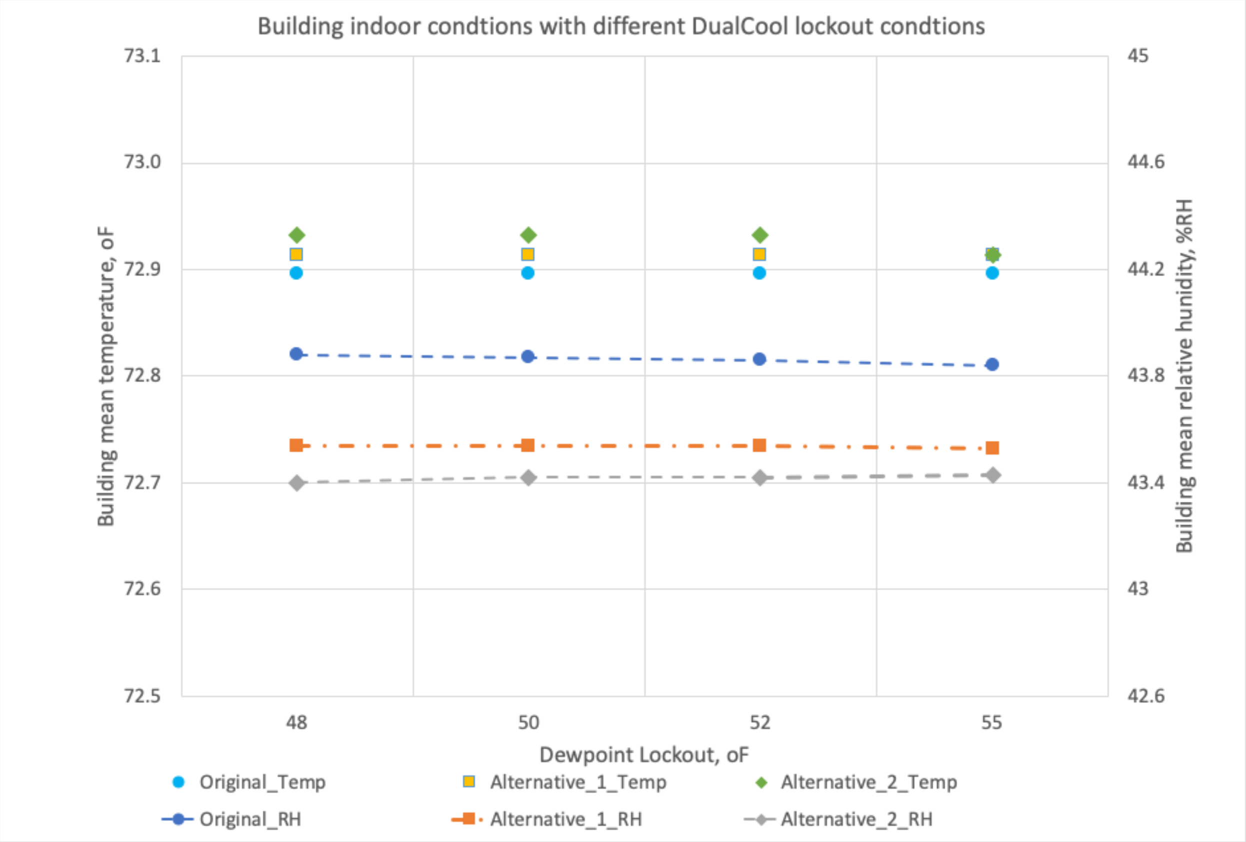


Figure G-4: Implications of increasing the DualCool dewpoint temperature lockouts on the mean dry-bulb and wet-bulb temperatures across all zones, annually, in the store

Appendix H. Impacts of Constant-Volume Fan Operation (Business-as-Usual) for RTU #8

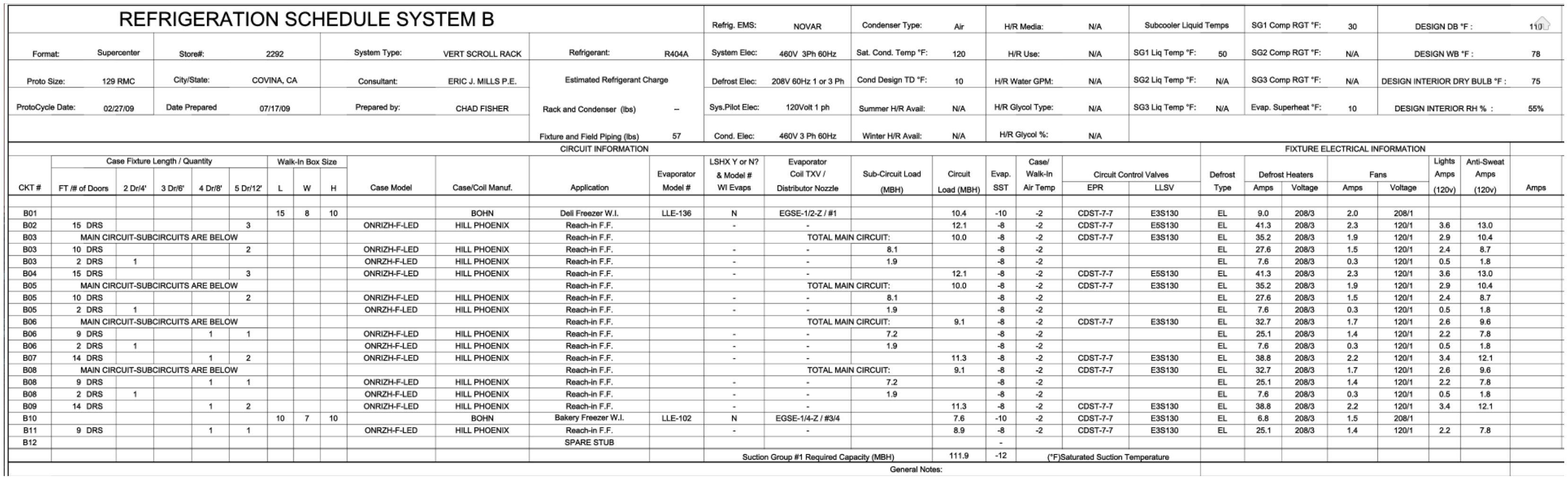
RTU 7 and 8 in the baseline model provide the air balance with exhaust fans in the McDonalds kitchen space, with a two-speed fan operation. However, the current proposed design for SMC retrofits suggest switching RTU 8 with a constant-volume supply fan, and RTU 7 with a variable-volume supply fan. In this section, we investigate an alternative SMC motor retrofit scenario where RTU 7 and RTU 8 are both converted to variable-air volume while maintaining a fixed and minimum outdoor air flowrate that is required for proper air balancing with local exhaust fans. The whole-building site electricity savings associated with this alternative SMC retrofit is summarized in Table H-1.

Table H-1: Whole-Building Site Electricity Savings Associated with an Alternative SMC Retrofit Approach

	Total Building Site Electricity Consumption (kWh)	Whole-Building Site Electricity Savings (%)
Current Proposed Design	3,318,221	7.03%
Alternative Design	3,185,621	7.15%

While the whole-building electricity savings impacts shown in Table H-1 do not include the remaining energy-efficiency measures and their interactive effects, it provides the relative impacts associated with this alternative SMC retrofit scenario. Although the increase in efficiency is not high, it may provide an additional increase in overall electricity savings for the store.

Appendix I. Refrigeration Schedules

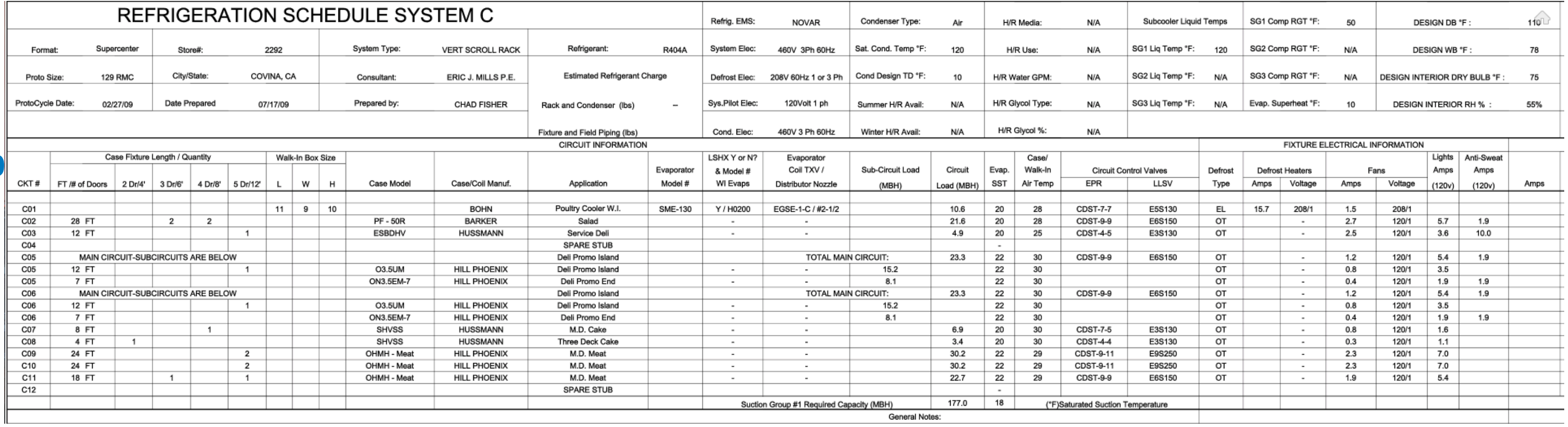


REFRIGERATION SCHEDULE SYSTEM B

								Refrig. EMS:	NOVAR	Condenser Type:	Air	H/R Media:	N/A	Subcooler Liquid Temps		SG1 Comp RGT °F:	30	DESIGN DB °F :	110
Format:	Supercenter	Store#:	2292	System Type:	VERT SCROLL RACK	Refrigerant:	R404A	System Elec:	460V 3Ph 60Hz	Sat. Cond. Temp °F:	120	H/R Use:	N/A	SG1 Liq Temp °F:	50	SG2 Comp RGT °F:	N/A	DESIGN WB °F :	78
Proto Size:	129 RMC	City/State:	COVINA, CA	Consultant:	ERIC J. MILLS P.E.	Estimated Refrigerant Charge		Defrost Elec:	208V 60Hz 1 or 3 Ph	Cond Design TD °F:	10	H/R Water GPM:	N/A	SG2 Liq Temp °F:	N/A	SG3 Comp RGT °F:	N/A	DESIGN INTERIOR DRY BULB °F :	75
ProtoCycle Date:	02/27/09	Date Prepared	07/17/09	Prepared by:	CHAD FISHER	Rack and Condenser (lbs)	–	Sys.Pilot Elec:	120Volt 1 ph	Summer H/R Avail:	N/A	H/R Glycol Type:	N/A	SG3 Liq Temp °F:	N/A	Evap. Superheat °F:	10	DESIGN INTERIOR RH % :	55%
						Fixture and Field Piping (lbs)	57	Cond. Elec:	460V 3 Ph 60Hz	Winter H/R Avail:	N/A	H/R Glycol %:	N/A						

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
CKT #	Case Fixture Length / Quantity					Walk-In Box Size			Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	Circuit Control Valves		Defrost Type	Defrost Heaters		Fans		Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H											EPR	LLSV		Amps	Voltage	Amps	Voltage			
B01						15	8	10		BOHN	Deli Freezer W.I.	LLE-136	N	EGSE-1/2-Z / #1		10.4	-10	-2	CDST-7-7	E3S130	EL	9.0	208/3	2.0	208/1			
B02	15 DRS				3				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-		12.1	-8	-2	CDST-7-7	E5S130	EL	41.3	208/3	2.3	120/1	3.6	13.0	
B03	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Reach-in F.F.			TOTAL MAIN CIRCUIT:		10.0	-8	-2	CDST-7-7	E3S130	EL	35.2	208/3	1.9	120/1	2.9	10.4	
B03	10 DRS				2				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	8.1		-8	-2			EL	27.6	208/3	1.5	120/1	2.4	8.7	
B03	2 DRS	1							ONRZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	1.9		-8	-2			EL	7.6	208/3	0.3	120/1	0.5	1.8	
B04	15 DRS				3				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-		12.1	-8	-2	CDST-7-7	E5S130	EL	41.3	208/3	2.3	120/1	3.6	13.0	
B05	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Reach-in F.F.			TOTAL MAIN CIRCUIT:		10.0	-8	-2	CDST-7-7	E3S130	EL	35.2	208/3	1.9	120/1	2.9	10.4	
B05	10 DRS				2				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	8.1		-8	-2			EL	27.6	208/3	1.5	120/1	2.4	8.7	
B05	2 DRS	1							ONRZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	1.9		-8	-2			EL	7.6	208/3	0.3	120/1	0.5	1.8	
B06	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Reach-in F.F.			TOTAL MAIN CIRCUIT:		9.1	-8	-2	CDST-7-7	E3S130	EL	32.7	208/3	1.7	120/1	2.6	9.6	
B06	9 DRS			1	1				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	7.2		-8	-2			EL	25.1	208/3	1.4	120/1	2.2	7.8	
B06	2 DRS	1							ONRZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	1.9		-8	-2			EL	7.6	208/3	0.3	120/1	0.5	1.8	
B07	14 DRS			1	2				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-		11.3	-8	-2	CDST-7-7	E3S130	EL	38.8	208/3	2.2	120/1	3.4	12.1	
B08	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Reach-in F.F.			TOTAL MAIN CIRCUIT:		9.1	-8	-2	CDST-7-7	E3S130	EL	32.7	208/3	1.7	120/1	2.6	9.6	
B08	9 DRS			1	1				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	7.2		-8	-2			EL	25.1	208/3	1.4	120/1	2.2	7.8	
B08	2 DRS	1							ONRZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-	1.9		-8	-2			EL	7.6	208/3	0.3	120/1	0.5	1.8	
B09	14 DRS			1	2				ONRIZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-		11.3	-8	-2	CDST-7-7	E3S130	EL	38.8	208/3	2.2	120/1	3.4	12.1	
B10						10	7	10		BOHN	Bakery Freezer W.I.	LLE-102	N	EGSE-1/4-Z / #3/4		7.6	-10	-2	CDST-7-7	E3S130	EL	6.8	208/3	1.5	208/1			
B11	9 DRS			1	1				ONRZH-F-LED	HILL PHOENIX	Reach-in F.F.		-	-		8.9	-8	-2	CDST-7-7	E3S130	EL	25.1	208/3	1.4	120/1	2.2	7.8	
B12											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			111.9	-12	(°F)Saturated Suction Temperature										

General Notes:



REFRIGERATION SCHEDULE SYSTEM C

								Refrig. EMS:	NOVAR	Condenser Type:	Air	H/R Media:	N/A	Subcooler Liquid Temps		SG1 Comp RGT °F:	50	DESIGN DB °F :	110
Format:	Supercenter	Store#:	2292	System Type:	VERT SCROLL RACK	Refrigerant:	R404A	System Elec:	460V 3Ph 60Hz	Sat. Cond. Temp °F:	120	H/R Use:	N/A	SG1 Liq Temp °F:	120	SG2 Comp RGT °F:	N/A	DESIGN WB °F :	78
Proto Size:	129 RMC	City/State:	COVINA, CA	Consultant:	ERIC J. MILLS P.E.	Estimated Refrigerant Charge		Defrost Elec:	208V 60Hz 1 or 3 Ph	Cond Design TD °F:	10	H/R Water GPM:	N/A	SG2 Liq Temp °F:	N/A	SG3 Comp RGT °F:	N/A	DESIGN INTERIOR DRY BULB °F :	75
ProtoCycle Date:	02/27/09	Date Prepared	07/17/09	Prepared by:	CHAD FISHER	Rack and Condenser (lbs)	–	Sys.Pilot Elec:	120Volt 1 ph	Summer H/R Avail:	N/A	H/R Glycol Type:	N/A	SG3 Liq Temp °F:	N/A	Evap. Superheat °F:	10	DESIGN INTERIOR RH % :	55%
						Fixture and Field Piping (lbs)		Cond. Elec:	460V 3 Ph 60Hz	Winter H/R Avail:	N/A	H/R Glycol %:	N/A						

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
CKT #	Case Fixture Length / Quantity					Walk-In Box Size			Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	Circuit Control Valves		Defrost Type	Defrost Heaters		Fans		Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H											EPR	LLSV		Amps	Voltage	Amps	Voltage			
C01						11	9	10		BOHN	Poultry Cooler W.I.	SME-130	Y / H0200	EGSE-1-C / #2-1/2		10.6	20	28	CDST-7-7	E5S130	EL	15.7	208/1	1.5	208/1			
C02	28 FT		2	2					PF - 50R	BARKER	Salad		-	-		21.6	20	28	CDST-9-9	E6S150	OT		-	2.7	120/1	5.7	1.9	
C03	12 FT				1				ESBDHV	HUSSMANN	Service Deli		-	-		4.9	20	25	CDST-4-5	E3S130	OT		-	2.5	120/1	3.6	10.0	
C04											SPARE STUB						-											
C05	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Deli Promo Island			TOTAL MAIN CIRCUIT:		23.3	22	30	CDST-9-9	E6S150	OT		-	1.2	120/1	5.4	1.9	
C05	12 FT				1				O3.5UM	HILL PHOENIX	Deli Promo Island		-	-	15.2		22	30			OT		-	0.8	120/1	3.5		
C05	7 FT								ON3.5EM-7	HILL PHOENIX	Deli Promo End		-	-	8.1		22	30			OT		-	0.4	120/1	1.9	1.9	
C06	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW										Deli Promo Island			TOTAL MAIN CIRCUIT:		23.3	22	30	CDST-9-9	E6S150	OT		-	1.2	120/1	5.4	1.9	
C06	12 FT				1				O3.5UM	HILL PHOENIX	Deli Promo Island		-	-	15.2		22	30			OT		-	0.8	120/1	3.5		
C06	7 FT								ON3.5EM-7	HILL PHOENIX	Deli Promo End		-	-	8.1		22	30			OT		-	0.4	120/1	1.9	1.9	
C07	8 FT			1					SHVSS	HUSSMANN	M.D. Cake		-	-		6.9	20	30	CDST-7-5	E3S130	OT		-	0.8	120/1	1.6		
C08	4 FT	1							SHVSS	HUSSMANN	Three Deck Cake		-	-		3.4	20	30	CDST-4-4	E3S130	OT		-	0.3	120/1	1.1		
C09	24 FT				2				OHMH - Meat	HILL PHOENIX	M.D. Meat		-	-		30.2	22	29	CDST-9-11	E9S250	OT		-	2.3	120/1	7.0		
C10	24 FT				2				OHMH - Meat	HILL PHOENIX	M.D. Meat		-	-		30.2	22	29	CDST-9-11	E9S250	OT		-	2.3	120/1	7.0		
C11	18 FT		1		1				OHMH - Meat	HILL PHOENIX	M.D. Meat		-	-		22.7	22	29	CDST-9-9	E6S150	OT		-	1.9	120/1	5.4		
C12											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			177.0	18	(°F)Saturated Suction Temperature										

General Notes:

REFRIGERATION SCHEDULE SYSTEM A

								Refrig. EMS:	NOVAR	Condenser Type:	Air	H/R Media:	N/A	Subcooler Liquid Temps		SG1 Comp RGT °F:	30	DESIGN DB °F :	110
Format:	Supercenter	Store#:	2292	System Type:	VERT SCROLL RACK	Refrigerant:	R404A	System Elec:	460V 3Ph 60Hz	Sat. Cond. Temp °F:	120	H/R Use:	N/A	SG1 Liq Temp °F:	50	SG2 Comp RGT °F:	N/A	DESIGN WB °F :	78
Proto Size:	129 RMC	City/State:	COVINA, CA	Consultant:	ERIC J. MILLS P.E.	Estimated Refrigerant Charge		Defrost Elec:	208V 60Hz 1 or 3 Ph	Cond Design TD °F:	10	H/R Water GPM:	N/A	SG2 Liq Temp °F:	N/A	SG3 Comp RGT °F:	N/A	DESIGN INTERIOR DRY BULB °F :	75
ProtoCycle Date:	02/27/09	Date Prepared	07/17/09	Prepared by:	CHAD FISHER	Rack and Condenser (lbs)	–	Sys.Pilot Elec:	120Volt 1 ph	Summer H/R Avail:	N/A	H/R Glycol Type:	N/A	SG3 Liq Temp °F:	N/A	Evap. Superheat °F:	10	DESIGN INTERIOR RH % :	55%
						Fixture and Field Piping (lbs)		Cond. Elec:	460V 3 Ph 60Hz	Winter H/R Avail:	N/A	H/R Glycol %:	N/A						

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
	Case Fixture Length / Quantity					Walk-In Box Size													Circuit Control Valves			Defrost Heaters		Fans				
CKT #	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H	Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	EPR	LLSV	Defrost Type	Amps	Voltage	Amps	Voltage	Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
A01						28	16	12		BOHN	1/2 Grocery / I.C. Freezer W.I.	BML-165	N	EGSE-1-Z / #1-1/2		13.7	-20	-10	CDST-7-9	E5S130	EL	16.0	208/3	3.6	208/1			
A02						28	16	12		BOHN	1/2 Grocery / I.C. Freezer W.I.	BML-165	N	EGSE-1-Z / #1-1/2		13.7	-20	-10	CDST-7-9	E5S130	EL	16.0	208/3	3.6	208/1			
A03	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A04	12 FT				1				FWG - FF	HUSSMANN	Dual Temp Coffin Island		-	-		7.5	-20	-10	CDST-7-7	E3S130	EL	23.1	208/1	3.1	120/1		0.2	
A05	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A06	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A07	20 FT			1	1				FWG - FF	HUSSMANN	Dual Temp Coffin Island		-	-		12.5	-20	-10	CDST-7-9	E5S130	EL	38.5	208/1	5.3	120/1		0.4	
A08	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A09	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A10	20 FT			1	1				FWG - FF	HUSSMANN	Dual Temp Coffin Island		-	-		12.5	-20	-10	CDST-7-9	E5S130	EL	38.5	208/1	5.3	120/1		0.4	
A11	6 FT		1						FWEG - FF	HUSSMANN	Dual Temp Coffin End		-	-		2.6	-20	-10	SDR-3-4	E3S130	EL	6.5	208/1	0.8	120/1		0.1	
A12	13 DRS		1		2				ONRZH-C-LED	HILL PHOENIX	Reach-in I.C.		-	-		13.6	-17	-10	CDST-7-9	E5S130	EL	36.2	208/3	2.0	120/1	3.1	11.3	
A13	12 DRS		1	1	1				ONRZH-C-LED	HILL PHOENIX	Reach-in I.C.		-	-		12.5	-17	-10	CDST-7-9	E5S130	EL	33.7	208/3	1.8	120/1	2.9	10.4	
A14											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			101.5	-23	(°F)Saturated Suction Temperature										
											General Notes:																	

REFRIGERATION SCHEDULE SYSTEM D

								Refrig. EMS:	NOVAR	Condenser Type:	Air	H/R Media:	N/A	Subcooler Liquid Temps		SG1 Comp RGT °F:	50	DESIGN DB °F :	110
Format:	Supercenter	Store#:	2292	System Type:	VERT SCROLL RACK	Refrigerant:	R404A	System Elec:	460V 3Ph 60Hz	Sat. Cond. Temp °F:	120	H/R Use:	N/A	SG1 Liq Temp °F:	120	SG2 Comp RGT °F:	N/A	DESIGN WB °F :	78
Proto Size:	129 RMC	City/State:	COVINA, CA	Consultant:	ERIC J. MILLS P.E.	Estimated Refrigerant Charge		Defrost Elec:	208V 60Hz 1 or 3 Ph	Cond Design TD °F:	10	H/R Water GPM:	N/A	SG2 Liq Temp °F:	N/A	SG3 Comp RGT °F:	N/A	DESIGN INTERIOR DRY BULB °F :	75
ProtoCycle Date:	2/27/2009	Date Prepared	7/17/2009	Prepared by:	CHAD FISHER	Rack and Condenser (lbs)	--	Sys.Pilot Elec:	120Volt 1 ph	Summer H/R Avail:	N/A	H/R Glycol Type:	N/A	SG3 Liq Temp °F:	N/A	Evap. Superheat °F:	10	DESIGN INTERIOR RH % :	55%
						Fixture and Field Piping (lbs)		Cond. Elec:	460V 3 Ph 60Hz	Winter H/R Avail:	N/A	H/R Glycol %:	N/A						

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
	Case Fixture Length / Quantity					Walk-In Box Size													Circuit Control Valves			Defrost Heaters		Fans				
CKT #	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H	Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	EPR	LLSV	Defrost Type	Amps	Voltage	Amps	Voltage	Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
D01						10	9	10		BOHN	Deli Cooler W.I.	SM-090	Y / H0150	EGSE-1-C / #2		8.3	25	35	CDST-7-7	E3S130	OT		-	1.8	120/1			
D02	24 FT			3					DX6XN	KYSOR//WARREN	M.D. Dairy		-	-		26.2	28	32	CDST-9-9	E6S150	OT		-	0.6	120/1	4.5		
D03	24 FT				2				O5DM - Beer	HILL PHOENIX	M.D. Produce w/ misters		-	-		31.6	29	36	CDST-9-9	E9S250	OT		-	1.9	120/1	4.2		
D04	24 FT				2				O5DM - Beer	HILL PHOENIX	M.D. Produce w/ misters		-	-		31.6	29	36	CDST-9-9	E9S250	OT		-	1.9	120/1	4.2		
D05	16 FT			2					O5DM - Beer	HILL PHOENIX	M.D. Produce w/ misters		-	-		21.0	29	36	CDST-9-9	E6S150	OT		-	1.4	120/1	2.8		
D06						10	7	10		BOHN	Bakery Cooler W.I.	ADT-090	Y / H0150	EGSE-1/2-C / #1-1/2		7.2	25	35	CDST-7-5	E3S130	OT		-	2.0	120/1			
D07	24 FT				2				DX6XN	KYSOR//WARREN	M.D. Dairy		-	-		26.2	28	32	CDST-9-9	E6S150	OT		-	0.8	120/1	4.5		
D08											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			152.1	23	(°F)Saturated Suction Temperature										
											General Notes:																	

REFRIGERATION SCHEDULE SYSTEM E

				Refrig. EMS: NOVAR	Condenser Type: Air	H/R Media: N/A	Subcooler Liquid Temps	SG1 Comp RGT °F: 50	DESIGN DB °F : 110
Format: Supercenter	Store#: 2292	System Type: VERT SCROLL RACK	Refrigerant: R404A	System Elec: 460V 3Ph 60Hz	Sat. Cond. Temp °F: 120	H/R Use: N/A	SG1 Liq Temp °F: 120	SG2 Comp RGT °F: N/A	DESIGN WB °F : 78
Proto Size: 129 RMC	City/State: COVINA, CA	Consultant: ERIC J. MILLS P.E.	Estimated Refrigerant Charge	Defrost Elec: 208V 60Hz 1 or 3 Ph	Cond Design TD °F: 10	H/R Water GPM: N/A	SG2 Liq Temp °F: N/A	SG3 Comp RGT °F: N/A	DESIGN INTERIOR DRY BULB °F : 75
ProtoCycle Date: 2/27/2009	Date Prepared 7/17/2009	Prepared by: CHAD FISHER	Rack and Condenser (lbs) --	Sys.Pilot Elec: 120Volt 1 ph	Summer H/R Avail: N/A	H/R Glycol Type: N/A	SG3 Liq Temp °F: N/A	Evap. Superheat °F: 10	DESIGN INTERIOR RH % : 55%
			Fixture and Field Piping (lbs)	Cond. Elec: 460V 3 Ph 60Hz	Winter H/R Avail: N/A	H/R Glycol %: N/A			

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
	Case Fixture Length / Quantity					Walk-In Box Size													Circuit Control Valves			Defrost Heaters		Fans				
CKT #	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H	Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	EPR	LLSV	Defrost Type	Amps	Voltage	Amps	Voltage	Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
E01	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW					33	7	11			Dairy Cooler W.I.		TOTAL MAIN CIRCUIT:			17.0	25	35	CDST-7-9	E6S150	OT		-	5.4	120/1			
E01a										BOHN	1/3 Dairy Cooler W.I.	SM-076	Y / H0150	EGSE-1/2-C / #1	5.7		25	35			OT		-	1.8	120/1			
E01b										BOHN	1/3 Dairy Cooler W.I.	SM-076	Y / H0150	EGSE-1/2-C / #1	5.7		25	35			OT		-	1.8	120/1			
E01c										BOHN	1/3 Dairy Cooler W.I.	SM-076	Y / H0150	EGSE-1/2-C / #1	5.7		25	35			OT		-	1.8	120/1			
E02	MAIN CIRCUIT-SUBCIRCUITS ARE BELOW					49	16	11			Dairy Cooler W.I. w/ drs.		TOTAL MAIN CIRCUIT:			38.7	25	35	CDST-17-11	E9S250	OT		-	8.0	120/1			
E02a										BOHN	1/3 Dairy Cooler W.I. w/ drs.	ADT-208	Y / H0300	EGSE-2-C / #4	19.3		25	35			OT		-	4.0	120/1			
E02b										BOHN	1/3 Dairy Cooler W.I. w/ drs.	ADT-208	Y / H0300	EGSE-2-C / #4	19.3		25	35			OT		-	4.0	120/1			
E03						49	16	11		BOHN	1/3 Dairy Cooler W.I. w/ drs.	ADT-208	Y / H0300	EGSE-2-C / #4		19.3	25	35	CDST-7-9	E6S150	OT		-	4.0	120/1			
E04	16 FT			2					O5DM - Beer	HILL PHOENIX	M.D. Beer		-	-		21.0	29	36	CDST-7-9	E6S150	OT		-	1.4	120/1	2.8		
E05	24 FT				2				O5DM - Beer	HILL PHOENIX	M.D. Beer		-	-		31.6	29	36	CDST-9-11	E9S250	OT		-	1.9	120/1	4.2		
E06						25	18	12		BOHN	Grocery Cooler W.I.	WKE-340	Y / H0500	SSE-3-C / #8		29.9	19	28	CDST-17-11	E9S250	EL	30.4	208/1	2.3	208/1			
E07											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			157.5	17	(°F)Saturated Suction Temperature										
												General Notes:																

REFRIGERATION SCHEDULE SYSTEM F

				Refrig. EMS: NOVAR	Condenser Type: Air	H/R Media: N/A	Subcooler Liquid Temps	SG1 Comp RGT °F: 50	DESIGN DB °F : 110
Format: Supercenter	Store#: 2292	System Type: VERT SCROLL RACK	Refrigerant: R404A	System Elec: 460V 3Ph 60Hz	Sat. Cond. Temp °F: 120	H/R Use: N/A	SG1 Liq Temp °F: 120	SG2 Comp RGT °F: N/A	DESIGN WB °F : 78
Proto Size: 129 RMC	City/State: COVINA, CA	Consultant: ERIC J. MILLS P.E.	Estimated Refrigerant Charge	Defrost Elec: 208V 60Hz 1 or 3 Ph	Cond Design TD °F: 10	H/R Water GPM: N/A	SG2 Liq Temp °F: N/A	SG3 Comp RGT °F: N/A	DESIGN INTERIOR DRY BULB °F : 75
ProtoCycle Date: 2/27/2009	Date Prepared 7/17/2009	Prepared by: CHAD FISHER	Rack and Condenser (lbs) --	Sys.Pilot Elec: 120Volt 1 ph	Summer H/R Avail: N/A	H/R Glycol Type: N/A	SG3 Liq Temp °F: N/A	Evap. Superheat °F: 10	DESIGN INTERIOR RH % : 55%
			Fixture and Field Piping (lbs)	Cond. Elec: 460V 3 Ph 60Hz	Winter H/R Avail: N/A	H/R Glycol %: N/A			

CIRCUIT INFORMATION																					FIXTURE ELECTRICAL INFORMATION							
	Case Fixture Length / Quantity					Walk-In Box Size													Circuit Control Valves			Defrost Heaters		Fans				
CKT #	FT /# of Doors	2 Dr/4'	3 Dr/6'	4 Dr/8'	5 Dr/12'	L	W	H	Case Model	Case/Coil Manuf.	Application	Evaporator Model #	LSHX Y or N? & Model # WI Evaps	Evaporator Coil TXV / Distributor Nozzle	Sub-Circuit Load (MBH)	Circuit Load (MBH)	Evap. SST	Case/ Walk-In Air Temp	EPR	LLSV	Defrost Type	Amps	Voltage	Amps	Voltage	Lights Amps (120v)	Anti-Sweat Amps (120v)	Amps
F01	12 FT				1				DR6XN	KYSOR//WARREN	M.D. Rear Load Dairy		-	-		17.4	26	32	CDST-9-7	E6S150	OT		-	1.6	120/1	1.5		
F02	24 FT				2				DR6XN	KYSOR//WARREN	M.D. Rear Load Dairy		-	-		34.8	26	32	CDST-17-11	E9S250	OT		-	3.1	120/1	3.0		
F03	24 FT				2				DX6XN	KYSOR//WARREN	M.D. Dairy		-	-		26.2	28	32	CDST-9-9	E6S150	OT		-	0.8	120/1	4.5		
F04	24 FT				2				DX6XN	KYSOR//WARREN	M.D. Dairy		-	-		26.2	28	32	CDST-9-9	E6S150	OT		-	0.8	120/1	4.5		
F05	12 FT				1				DX6XN	KYSOR//WARREN	M.D. Dairy		-	-		13.1	28	32	CDST-7-5	E5S130	OT		-	0.4	120/1	2.3		
F06						22	18	12		BOHN	Produce Cooler W.I.	WK-270	Y / H0300	EGSE-2-C / #4		20.1	28	36	CDST-9-9	E6S150	OT		-	3.6	120/1			
F07											SPARE STUB						-											
													Suction Group #1 Required Capacity (MBH)			137.7	24	(°F)Saturated Suction Temperature										
												General Notes:																