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Subject: Phase Two: SBCC Commercial Modeling Analysis Plan

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Purpose

This document describes the analysis plan for the Phase Two effort to revise the performance estimates of the 2006 commercial baseline for SBCC. This project will focus on key variables that Phase One analysis suggested needed additional evaluation to more accurately portray the actual performance of the 2006 building stock. In particular, we propose to identify the degree to which performance predictions are sensitive to specific changes to modeling inputs, based on a range of values suggested by market research on building characteristics and operating patterns. This analysis will also help to identify the significance of specific performance variables on observed variability between modeled and measured performance and provide a basis for evaluating the impacts of some market trends outside of code requirements on overall building performance.

To establish some boundaries on this analysis, Phase Two will focus on prototypes or prototype groups, such as "Offices" or "Schools" or "Restaurants", that were determined to contribute significantly to statewide energy use in Phase One of this modeling study. Adjustments made will be based on recent RTF updates and Ecotope's literature review and research into building assessment and operations studies. In addition to modeling adjustments, post processing will account for potential changes in system distribution and the effect of HVAC equipment faults and poor operation.

This analysis plan has been developed to summarize the approach taken to revise the modeling method for key building types and performance issues and to incorporate market research to identify alternate input values to more closely match anticipated characteristics in the building stock. A summary of the current research and potential sources are attached as an Appendix to this document.

Prototype Analysis Priorities

Table 1 below shows the percentage of total sector energy use that each prototype contributed to the total statewide building stock energy usage, based on analysis results in Phase One of this study. For Phase Two, we propose to focus on prototypes or prototype groups that contributed to over 5% of the statewide energy use total, in either the 2006 baseline or the 2018 models. For each prototype group that represents over 5% of the total energy use (ex. "Office"), one representative prototype from the group will be adjusted and the effects will be extrapolated to the other prototypes within the group. For example, a plug load sensitivity analysis run for medium office will be used to extrapolate result adjustments for large office and small office.

The **bolded** prototypes from Table 1 are models that will be modified in the first round of this analysis. Specific modifications proposed for these prototypes are described for each prototype below to illustrate our approach, however, initial analysis results may identify a few additional values that should be explored. Once the individual impacts have been studied, Ecotope will identify a set of key variables to apply to the models to produce revised 2006 baseline results.

Note that although the hospital prototype contributed significantly to total statewide energy use, performance variability in hospitals is driven primarily by the mix of specialized services provided at any given hospital, and this does not lend itself to generalization. The results for the hospital prototype from Phase One appeared within reason compared to market results, so this building type is omitted from the Phase Two sensitivity analysis.

Table 1. Phase One Prototype Results by Percent of Total Energy Use

Category	Sub-Type	% 2006 Total Energy use	% 2018 Total Energy Use
Retail			
	Retail stand-alone	**17%**	**13%**
	Retail supermarket	**7%**	**8%**
	Retail strip-mall	3%	2%
Office			
	Office large	6%	6%
	Office medium	**6%**	**5%**
	Office small	4%	3%
Health			
	Health outpatient	**10%**	**11.5%**
	Hospital	8%	8%
	Health residential care	5%	6%
Multifamily			
	Multifamily mid-rise	**4%**	**4.5%**
	Multifamily high-rise	0.5%	0.5%
Hotel			
	Large Hotel	7.%	8%
	Small Hotel	1%	1%
Restaurant			
	Full-service	**9%**	**10.5%**
	Quick-service	4.5%	5%
School			
	Primary School	**4%**	**4%**
	Secondary School	1.5%	1.5%
Warehouse	Unrefrigerated Warehouse	3%	2%

Summary of Analysis Variables by Prototype

For each prototype below, we've summarized modeling modifications to better reflect actual building construction and system operation.

Stand-alone Retail

The stand-alone retail was the largest energy user from Phase One modeling efforts due to the significant portion of statewide square footage that it represents. In the 2006 runs, a significant portion of its energy usage was attributed to heating, indoor lighting, and fans. Heating and fan energy use were reduced significantly in 2018 due to implementation of Dedicated Outside Air System (DOAS) requirements within code, making indoor lighting and receptable the highest end-uses.

Stand-alone retail buildings are diverse and can encompass anything from a small boutique shop to an electronics store to a 24/7 convenience store – this variety is most closely associated with changes in usage schedules and internal loads. Schedule changes will be based on updated RTF values and internal gains will be adjusted per market research. The results for this sensitivity analysis will be used to assess and adjust energy usage from retail strip-malls as well.

Table 2. Stand Alone Retail Adjustments

Stand Alone-Retail				
Modeling Update	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Miscellaneous Loads (x1)	System A (x1)	(x2)	(x2)	4
RTF Schedule Adjustments (x2)	System A (x1)	(x2)	(x2)	8

Health Outpatient

Health Outpatient contributed significantly to the statewide energy use, both due to high energy consumption and its portion of total statewide area. However, this Phase Two study is an opportunity to change various RTF assumptions to create a prototype that more accurately reflects the building stock. For instance, the RTF Outpatient Healthcare building contains operating rooms, MRI rooms, and other intensive programming which, depending on how outpatient healthcare is defined, are not typical. The floor area weighting derived from the 2014 Commercial building Stock Assessment suggests that the square footage for outpatient healthcare should be modeled as a less use-intensive building, more representative of family practitioners and dentists. These buildings do not typically have ventilation systems designed per ASHRAE 170, which requires a large amount of recirculated air; space types and ventilation requirements will be adjusted per Table 3 to resemble standard outpatient healthcare more closely and space types shown in red will be removed from the model completely.

Along with the adjustment of space types and ventilation, one new HVAC system will be added – a central packaged VAV (PVAV), with central gas heating, central DX cooling, and electric reheat – for both 2006 and 2018 baselines. This will give us a high and low intensity outpatient healthcare building and allow us to assess the overall building stock more accurately.

Table 3. Space Type and Ventilation Adjustments for Health Outpatient

Space Type	Space Type (Abbr.)	Phase Two-Updated Space Type	Ventilation Adjustment
Nurse Station/…	NURS		X
Storage, Janitor, Utility	ASTO		
Dinning	DINN		
Work/Dictation/Dressing/IT/Scheduling	WORK		X
Mechanical Room	MECH		
Elevator Pump Room	ELPR		
Hallway	CORR		
Lobby	LBBY		
Restroom	REST		
Locker Room	LOCK		
Lounge	LUNG		
MRI Room	MRIR	EXAM	X
Office	OFFC		
Operation Room	OPRM	EXAM	X
Procedure Room	PRCR	EXAM	X
Pre-Op Room	PREO	EXAM	X
Recovery Room	RCVY	EXAM	X
Vestibule	VEST		
Conference room	CONF		
Exam Room	EXAM		X
Reception	RECP		X
X-Ray	XRAY	EXAM	X
Physical Therapy	PHYC		X
Stairs	STRS		
Elevator	ELVE		

Table 4. Outpatient Healthcare Adjustments

Outpatient Health Care				
Change	Mechanical System	Years	Weather Files	Total Runs
Space Type and Mechanical System Changes	(x1)	(x2)	(x2)	4

Full-Service Restaurant

The Full-Service Restaurant building type had a significant statewide energy impact with the largest end-uses consisting of process loads (cooking), space heating, and kitchen exhaust fans. For this analysis, Ecotope recommends both an exhaust air configuration adjustment and a sensitivity analysis of kitchen process and receptacle loads.

The current model is set up with the exhaust fan drawing conditioned air from the kitchen, with transfer air from the dining area. However, many modern kitchen hood designs have a direct make-up air connection to the kitchen hood that does not cool incoming air and only heats to 55°F. To avoid complications with trying to model such a system in detail, Ecotope recommends reducing the kitchen heating setpoint to 55°F during operating hours and removing any cooling setpoint.

Sensitivity analysis on the amount of process energy used in a commercial kitchen, the amount of heat that is directly exhausted through the exhaust hood, and schedules to represent different operating hours should be performed to represent the range of full-service restaurants. The changes made for full service and modeling results will also be used to adjust results for quick service restaurants, which is in the same prototype group.

Table 5. Full-Service Restaurants Adjustments

Full-Service Restaurants				
Change	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Exhaust Fan Adjustment	System A (x1)	(x2)	(x2)	4
Plug and Process Adjustments (x4)	System A (x1)	(x2)	(x2)	16
RTF Schedule Adjustments (x2)	System A (x1)	(x2)	(x2)	8

Retail Supermarket

Retail supermarkets include significant refrigeration system loads. However, depending on the type of grocery store, the density of refrigeration systems can vary significantly. Additionally, different grocery stores have different operating hours not captured by Phase One analysis. Ecotope recommends two sensitivity analyses on this prototype, one which increases the amount of refrigeration being modeled, and another that adjusts schedules to the updated RTF schedules.

Table 6. Retail Supermarket Adjustments

Retail Supermarket				
Change	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Refrigeration Adjustment (x1)	System A (x1)	(x2)	(x2)	4
RTF Schedule Adjustments (x2)	System A (x1)	(x2)	(x2)	8

Medium Office

The medium office prototype will be used to represent all three office prototypes – small, medium, and large – in a sensitivity analysis focused on adjusting schedules (to updated RTF schedules) and plug loads. In addition, this prototype will be used to explore energy use sensitivity more deeply in relation to specific code sections and window-to-wall ratios.

Although it is not feasible to run code section upgrades or adjust window to wall ratio across all prototypes, it is important to capture these details in order to inform future code cycles. To assess the impact that different code sections have on energy use, the 2006 model will be upgraded one code section at a time (Sections C402, C403, C405, and C406).

Table 7. Medium Office Adjustments

Medium Office				
Change	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Miscellaneous Loads (x1)	System A (x1)	(x2)	(x2)	4
RTF Schedule Adjustments (x2)	System A (x1)	(x2)	(x2)	8
Window to Wall Ratio (x2)	System A (x1)	(x2)	(x2)	8
Code Section (x4)	System A (x1)	-	(x2)	8

Primary School

In the RTF prototypes for schools, the assumed plug and process loads seem higher than observed in actual design and operation. This leads to a significant reduction in modeled heating energy which could result in incorrect conclusions about actual building energy performance. A plug and process load sensitivity analysis is recommended for these prototypes, along with a review and update of building schedule assumptions. Additionally, a condensing boiler should be modeled for 2006 runs to better represent equipment types installed in the building stock at the time.

Table 8. Primary School Adjustments

Primary School				
Change	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Miscellaneous Loads (x1)	System A (x1)	(x2)	(x2)	4
RTF Schedule Adjustments (x2)	System A (x1)	(x2)	(x2)	8

Multifamily Mid-Rise

Multifamily buildings contributed to 5% to the total energy use for commercial buildings in Washington. The end-use break down for multifamily in the modeling analysis did not align with extensive field analysis on this building type conducted by Ecotope. To remedy this, we propose to modify the input values for hot water and plug load end uses to assess whether more accurate modeling can be achieved for this building type. Results of this analysis may suggest the need for similar modifications to hotel and residential health care prototypes.

Table 9. Mid-rise Apartment Adjustments

Mid-rise Apartment				
Change	**Mechanical System**	**Years**	**Weather Files**	**Total Runs**
Internal Load Adjustment (x1)	System A (x1)	(x2)	(x2)	4
Hot Water Usage (x1)	System A (x1)	(x2)	(x2)	4

Research and Information Resources Appendix

Prepared_for	Year	Prepared_by	Topic	Building Type	Title
ACEEE	2008	Richman, E. et al. (PNNL+)	Building Characteristics	Most commercial types	National Commercial Construction Characteristics and Compliance with Building Energy Codes: 1999-2007
Readership	2018?	GE current (lighting products company)	Building Characteristics	Retail - grocery	How is the Grocery Store Footprint Changing?
NEEA	2004	Ecotope	CBSA	Most commercial types	Baseline Characteristics of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon and Washington
NEEA	2008	Ecotope	CBSA	Most commercial types	Baseline Energy Use Index of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon and Washington
NEEA	2009	Cadmus + Ecotope	CBSA	Most commercial types	Northwest Building Stock Assessment
NEEA	2014	Navigant	CBSA	Most commercial types	2014 Commercial Building Stock Assessment: Final Report
NEEA	2019	Cadmus	CBSA	Most commercial types	Commercial Building Stock Assessment 4 (2019) Final Report
Proceedings of the IEEE	2011	Baliga, et al.	Cloud Computing	Many commercial types	Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport
NREL	2011	Sheppy, M. et al. (NREL)	Cloud Computing	Office	Reducing Data Center Loads for a Largescale, Low-energy Office Building: NREL's Research Support Facility
IEEE Cloud Computing	2015	Mastelic, T. and Brandic, I.	Cloud Computing	General commercial	Recent Trends in Energy-Efficient Cloud Computing
Forbes	2018	Columbus, L.	Cloud Computing	Many commercial types	State Of Enterprise Cloud Computing, 2018
Energy Innovation	2020	Masanet, E. and Lei, N. (NREL +)	Cloud Computing	General commercial	How Much Energy Do Data Centers Really Use?
NBI	2015	Frankel, M. and Edelson, J. (NBI)	Code Road Map	General commercial	Washington State Energy Code Roadmap
DOE	2015	PNNL	Code Road Map	General commercial	Roadmap for the Future of Commercial Energy Codes
NEEA	2008	NEEA	Commercial Code	General commercial	Non-Residential Energy Savings From Northwest Energy Code Changes 2005-2008
DOE	2005	TIAX	Commissioning	General commercial	Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential
NEEA	2016	Cadmus	Commissioning	General commercial	Commissioning LongTerm Monitoring and Tracking—2015 Square-Footage Update (2016 Study)
PNNL	2017	PNNL	Commissioning	Many commercial types	Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction
Slipstream	2018	Slipstream	Commissioning	General commercial	Persistence of Savings from Retro-Commissioning Measures
PNNL	2019	PNNL	Commissioning	Many commercial types	Basic HVAC Controls and Energy Codes ?
CEUS	2006	Itron	End Use	Most commercial types	California Commercil End-use Survey
DOE	2010	PNNL	End Use	Hotel	Energy End-Use Patterns in Full-Service Hotels: A Case Study
DOE	2014; Data from 2012	Sheppy, M. et al. (NREL)	End Use & Plug loads	Hospitals, Healthcare office	Healthcare Energy End-Use Monitoring
Seattle Office of Sustainability & Environment	2013	Seattle Office of Sustainability & Environment	Energy Benchmarking	General commercial	Building Energy Benchmarking Analysis Report 2013 Data
City of Portland	2018	Portland Bureau of Planning and Sustainability	Energy Benchmarking	Many commercial types	2018 Building Energy Performance Reporting Results
DOE		Various	Energy Benchmarking	Many commercial types	Policy, Permit, Perform: Using City Benchmarking Data and Building Construction Permit History to Identify Energy Performance Improvements
Legislature	2015	Energy Codes Council	Energy Code	Residential, General commercial	Washington state Energy Code Progress toward 2030
DOE	2016	Bartlett, R., et al. (PNNL)	Energy Code	Most commercial types	Commercial Building Energy Code Compliance Literature Review
U.S. Energy information Administration	2007	CBECS	Energy Use	Hospital - large	Energy Characteristics and Energy Consumed in Large Hospital Buildings in the United States in 2007
ASHRAE	2016	Glazer	Energy Use	Most commercial types	Development of Maximum Technically Achievable Energy Targets for Commercial Buildings.
Energy and Buildings	2019	Ye, Y. et al.	Energy Use	General commercial	A Comprehensive Review of Energy-Related Data for U.S. Commercial Buildings
NEEA	2007	LBNL	Envelope - Windows	Office	Analysis of window energy savings in commercial buildings in the Pacific Northwest
Readership	2010	BuildingGreen	Envelope - Windows	Many commercial types	It's Time to Rethink the All-Glass Building
DOE	2015	PNNL	Envelope - Windows +	multi-family/office, mixed use	Preserving Envelope Efficiency in Performance Based Code Compliance
DOE	2018	Winiarski, D. et al. (PNNL)	Envelope + HVAC	Most commercial types	Analysis for Building Envelopes and Mechanical Systems Using 2012 CBECS Data

Slipstream	2015	Slipstream	Lighting	General commercial	Adjusting lighting levels in commercial buildings
EIA	2017	EIA	Lighting Controls	General commercial - large	Large commerial buildings more likely to use lighting control strategies
City of Seattle	2015	ARUP	Mechanical - HVAC	Many commercial types	Seattle High-Efficiency Space Heating Recommendations for Market Transition
BPA	2015	Cadeo+	Mechanical - HVAC	Residential	Commercial HVAC Market Characterization - 2015 Findings
Whole Building Design Guide	2016	Graham, C. (Viridian Energy & Environmental, Inc.)	Mechanical - HVAC	General commercial	High-Performance HVAC
CEE	2016	CEE	Mechanical - HVAC	Many commercial types	High Efficiency Commercial Air-conditioning and Heat Pumps Initiative
BPA	2018	Cadeo+	Mechanical - HVAC	General commercial	HVAC Technoflogy Guide
Readership	2020	Statista	Mechanical - SHW	General commercial	Commercial gas and electric storage water heater shipments in the U.S. from 2001 to 2019
DOE	2011	PNNL	MELs	Hotel	Assessing and Reducing Miscellaneous Electric Loads (MELs) in Lodging
ACEEE	2012	Lanzisera, S., et al. (PNNL+)	MELs	Office	Methods for detailed energy data collection of miscellaneous and electronic loads in a commercial office building
EIA	2013	Navigant Consulting & SAIC	MELs	General commercial	Analysis and Representation of Miscellaneous Electric Loads in NEMS
ACEEEDC	2013	Kwatra, et al.	MELs	Residential, General commercial	Micellaneous Energy Loads in Buildings
DOE	2005?	Fanara, et al. (EPA+)	MELs	Residential, offices, schools	How Small Devices are Having a Big Impact on U.S. Utility Bills
ASHRAE	Various	ASHRAE	Model Comparison	Most commercial types	ASHRAE 90.1 - various years - Energy Standard for Building Except Low-Rise Residential Buildings
EIA	2016; Data from 2012	EIA	Model Comparison	Most commercial types	Electricity consumption totals and conditional intensities by building activity subcategories, 2012
ASHRAE	2013; Data from 2009-2011	Duarte, C., et al. (University of Idaho, Idaho National Laboratory)	Occupancy	Office	Revealing Occupancy patterns in an office building through the use of occupancy sensor data
LBNL	2004	Roberson, J. et al. (LBNL)	Plug Loads	Many commercial types	After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-load Equipment
Science Direct	2011	Srinivasan, R., et al.	Plug Loads	K-12 schools	Plug-load densities for energy analysis: K-12 schools
CEC	2011	ECOS	Plug Loads	Office	Office Plug Load Field Monitoring Report - PIER Final Project Report
ACEEE	2012	Acker, B. et al. (University of Idaho)	Plug Loads	Office	Office Space Plug Load Profiles and Energy Saving Interventions
NREL	2012	Locato, C, et al. (NREL)	Plug Loads	Office	Selecting a Control Strategy for Plug and Process Loads
GSA	2013	Institute for the Built Environment	Plug Loads	Office	Plug Load Research Review Summary
NREL	2013	NREL	Plug Loads	Office	Assessing and Reducing Plug and Process Loads in Office Buildings
Science Direct	2014	Fuentes, G. And Schiavon, S. (Center for the Built Environment)	Plug Loads	Office	Plug load energy analysis: The role of plug loads in LEED certificationand energy modeling
NREL	2014	Sheppy, M, et al. (NREL)	Plug Loads	Office, Higher Education	An Analysis of Plug Load Capacities and Power Requirements in Commercial Buildings
U.S.Dept. Energy	2014	Sheppy, M. et al. (NREL+)	Plug Loads	Office, Higher Education	Plug and Process Loads Capacity and Power Requirements Analysis
EIA	2017	EIA	Plug Loads	Education	Computer and technology use in education buildings continues to increase
Cadmus	2017	Cadmus	Plug Loads	Multifamily, Office, K-12 Schools	Variance and Optimization in Nonresidential Building Simulation Receptacle Loads
DOE-BetterBuildings	2018?	NREL	Plug Loads	Office	Office Building Plug Load Disaggregation
DOE-BetterBuildings	Various	DOE	Plug Loads	Many commercial types	Better Buildings Plugs and Process Loads - website resources
Readership	2000	US teleworkers	Remote Workforce	Office, other?	Telework In the US Telework America Survey 2000
CEA	2007	TIAX	Remote Workforce	Office	The Energy and Greenhouse Gas Emissions Impact of Telecommuting and e-Commerce
Sun Microsystems	2008	Sun Microsystems	Remote Workforce	Office	Sun Microsystems Study Finds Open Work Program Saves Employees Time and Money, Decreases Carbon Output
US Census	2010	US Census	Remote Workforce	Office, other?	Home-Based Workers in the US: 2010
American Psychological Association	2019	Greenbaum, Z.	Remote Workforce	Office, other?	The future of remote work
Readership	2019	Volusion	Remote Workforce	Office, other?	Cities With the Most Remote Workers
Readership	2020	Gallup	Remote Workforce	Office	Is Working Remotely Effective? Gallup Research Says Yes

Readership	2020	Global Workplace Analytics	Remote Workforce	Office, other?	Latest Work-At-Home/Telecommuting/Mobile Work/Remote Work Statistics
Readership	2020	KOMO	Remote Workforce	Office, other?	New study finds that nearly 8% of Seattleites work remotely
Readership		Flexjobs	Remote Workforce	Office, other?	Remote Work Statistics: Shifting Norms and Expectations
DOE	2015	DOE	Various	Many commercial types	Quadrennial Technology Review - An Assessment of Energy Technologies and Reseach Opportunities
EIA	2017	EIA	Various	General commercial - large	Commercial Buildings Energy Consumption Survey (CBECS)
NEEA	2019	Ecotope	Various	Select commercial	2019 Oregon New Commercial Construction Code Evaluation Study
DOE	2020	Ecotope	Various	Multifamily	Residential Building Energy Efficiency Field Studies: Low-Rise Multifamily
ASHE	?	ASHE	Various	Hospitals	Sustainability Roadmap for Hospitals
Slipstream	2015	Slipstream	Ventilation	General commercial	Energy savings from implementing and commissioning demand control ventilation