An Energy Calculator for Simple Commercial Buildings

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ABSTRACT

According to the EIA, simple commercial buildings account for 97% of total commercial building stock. However, most simple commercial buildings—for example small- to mid-sized offices, retail, schools and warehouses—do not benefit from the data-driven decision-making capabilities of whole-building energy modeling. The high cost of custom modeling limits the use of energy modeling of simple buildings for new construction or retrofit measures. Lack of tools providing helpful information on interactive savings estimates creates difficulties in meeting aggressive decarbonization and energy efficiency goals for simple building designers and utility program managers.

This paper reviews a beta phase Simple Building Calculator with the ability to generate relatively accurate and interactive modeling results based on a limited but robust set of inputs. It can evaluate whole-building or single measure savings in new or existing buildings, compare measure package choices, or provide simplified performance modeling for energy codes and utility incentives. The tool combines physical (annual whole building prototype simulation) and statistical modeling techniques to predict annual energy performance. It supports a variety of building characteristics for envelope, HVAC, and lighting with parameters ranging from vintage to max tech configurations, as well as support for single-zone and simple multi-zone HVAC systems. The Simple Building Calculator was designed to provide immediate feedback for otherwise computationally intensive tasks like measure comparison, development of multiple measure package combinations, or verification that measures meet efficiency targets—all with the goal of providing a tool for quick annual energy simulation of simple commercial buildings.

Introduction

Commercial buildings are responsible for a significant share of the overall U.S. building energy footprint as they account for approximately 61% of total U.S. electricity and 32% of natural gas (EIA 2012a) consumption. The Commercial Building Energy Consumption Survey report published by the U.S. Energy Information Administration estimates 97% of all commercial buildings have building area less than 50,000 square feet (EIA 2012b). Today, most small commercial buildings are designed following prescriptive requirements set by building energy codes and use simplified calculations for estimating building energy use, resulting in lost energy saving opportunities. Computer simulations conventionally called whole-building energy modeling (BEM) programs are known to produce highly accurate quantitative estimates of energy use by employing physics-based calculation of thermal loads to simulate energy performance of building systems (DOE 2019). BEM can be used for analyzing design, comparing efficiency options, showing compliance with regulatory requirements or for predicting annual and peak building energy usage. However, time and expert knowledge required for its effective use often discourage use of BEM programs in small commercial building applications.

Researchers at the Pacific Northwest National Laboratory (PNNL) proposed potential solutions (Hart et al. 2016; Rosenberg and Hart 2014) including simple tools based on precalculated packages of efficiency measures simulated on prototypical building energy models. The concept of a tool with pre-calculated simulation results was evaluated as an option to improve consistency, adoptability and design flexibility of model energy codes (Hart et al. 2016; Rosenberg and Hart 2014); and was tested in the context of a performance modeling path to achieve ZNE codes in California (Contoyannis et al. 2018). The tool uses whole building simulation using BEM programs to determine the independent and interactive impact of multiple parameters on building energy use. The simulation results are then used to develop calculation methods with regression formulas. The regressions are packaged in a spreadsheet-based tool capable of creating packages of trade-able efficiency measures. Such tools combine benefits of complex BEM capabilities with simplicity of a spreadsheet into a simple workflow; allowing simple building projects rapid access to whole building simulation results.

We applied this concept to develop the Simple Building Calculator (SBC), a spreadsheet-based tool for generating relatively accurate and interactive modeling results for small commercial buildings based on a limited but robust set of inputs. SBC supports a range of building types including small to mid-sized offices, retail, schools, warehouses, small hotels and mid-sized apartment buildings and can support common energy efficiency measures in these building types. This paper provides an overview of the SBC tool and its potential applications for addressing the challenging small commercial building sector toward higher energy efficiency.

Background

Small commercial buildings are typically subject to the prescriptive requirements in energy codes and deemed utility incentive programs. Barriers to moving energy use toward net zero in these smaller commercial buildings include:

- Completing custom modeling of the buildings is expensive relative to energy savings potential, yet going beyond deemed savings, prescriptive code items, or rating system savings would typically require energy modeling.
- Simplified tools that provide interactive savings based on simple input are not available, reducing the likelihood of a comprehensive integrated package of measures.
- In energy codes, the advance of prescriptive energy efficiency has reached a limit, in that there is much industry pressure against moving the prescriptive limits that apply to all buildings further. However, when advanced efficiency options are made flexible, pushing the efficiency envelope becomes much more acceptable to various stakeholders.
- Prescriptive approach to energy codes focuses on individual components rather than take a systems approach that can embrace emerging technologies and incorporate an integrated buildings systems approach to achieving aggressive savings.
- In utility incentive programs, new construction for small buildings is usually limited to prescriptive incentives. The lack of reliable savings estimates—acceptable to utility regulators—for a broad range of measures limits high efficiency or net-zero smaller buildings.
- Managers of large portfolios, like the GSA and other real estate managers, may desire or be required to make some form of individual building energy assessment, and may benefit from less than full BEM for simpler buildings.
- There are similar barriers to applying green or efficiency rating systems to smaller buildings.

Applications

The Simple Building Calculator will provide a quick energy estimate for interactive savings in simple buildings. While the tool is not intended for precise results, it will compare interactive impact of various measure combinations quickly and allow selection of packages of integrated design options for simple commercial buildings to achieve target levels of energy efficiency compared to a standard baseline design without custom simulation. These savings can be applied to energy codes, utility incentive programs, building rating programs, or advanced design efforts. The SBC engine is flexible and allows parameters to be included for either individual buildings or as a batch process versus a certain vintage of code building. Applications can include:

- Building designers can quickly evaluate various combinations of efficiency measures. The tool can be used for evaluating efficiency options for schematic design of new construction.
- Energy codes and standards can incorporate tradeoffs and interactive system efficiency improvements for simple buildings, moving beyond prescriptive.
- Utility program managers can evaluate measures for incentive deployment.
- The tool provides a simplified method to tackle comprehensive retrofits in the small commercial buildings, moving beyond single measure deemed savings.
- More comprehensive retrofit project designs can be tackled. SBC results indicate relative measure savings potential in existing buildings, but it is not designed to be tuned to specific existing building schedules or energy bill histories.
- Emerging technology program managers can review different measure groups to spot the largest potential energy savings; helping to focus research budgets.
- SBC can also be used for measure comparison, creation of multiple measure combinations, or verification that measure combinations meet efficiency targets.

Saving Measures Available

SBC uses a parametric approach with regressions to provide an interactive energy impact result. The parameters are fairly high level, and multiple measures can be modeled by adjusting individual parameters. Table 1 shows the list of parameters used and the related measures that can be modeled with each parameter.

Table 1. Input parameters and measures that can be modeled in SBC

Symbol	Input Parameter	Measures that can be modeled in SBC
Building Envelope		
GER	Glazing to envelope area ratio (window + skylight) / (wall + roof)	Window area skylight area
Uavg	Average envelope heat loss: (∑UA) / ∑A	Wall insulation Window conductivity reduction Perimeter slab insulation Roof insulation Floor insulation Underground wall insulation

Symbol	Input Parameter	Measures that can be modeled in SBC
Leak	Envelope leakage, cfm/sq ft of envelope area @75pa	Envelope air barrier installation Envelope leakage testing Vestibule and air curtains
SHGC	SHGC, including shading adjustments	Window SHGC reduction Added window shading Skylight SHGC reduction
Interior Loads (Lighting & Miscellaneous Electric Loads (MEL))		
LPD	Interior W/sq ft	Lamp efficacy increase Fixture efficacy increase
Adl	% of gross floor area with daylight controls	Increases in daylit area Light shelves Increase in perimeter area
Aos	% of gross floor area with occupancy lighting controls	Increases in area with occupancy sensors Shorter time out for occupancy sensors Smaller occupancy sensor control area
Aplug	% of gross floor area with 50% plug load control	Unoccupied period plug load control Energy efficient office equipment
HVAC System - Basic Efficiency and Operation		
SYS	HVAC System Type	Select system type for each case to see relative energy performance
cCOP	Cooling Nominal COP (efficiency)	System cooling efficiency improvement Incl: EER; COP; IEER; SEER
hEt	Heating Efficiency (Et or HSPF)	System heating efficiency improvement Incl: Et; Ec; HSPF; COPh
FanPwr	Total Fan power in W/cfm	Ductwork improvement Fan efficiency improvement Fan motor efficiency improvement Fan drive efficiency improvement
FanCtrl	VAV Fan % turndown minimum or fan speeds and control approach: CV, multi-speed, cycling, or VAV	2- or 3-Speed fan Enforced fan cycling with DOAS Variable speed drive (VSD) for fan Lower turndown for VSD
FanExtra	Extra hours (warmup and after occupancy) fan is ON and OA damper OPEN Mon-Sat	Optimum start Optimum stop OSA damper control
Econ	OA Econo high limit lockout temperature, DB (°F)	Addition of OSA economizer Improved integration of OSA economizer Improved setup of OSA economizer
OSA	Average annual % of 62.1 Design Outside air, occupied	Demand Controlled Ventilation (DCV) by CO2 DCV by occupancy sensor VAV outside air optimization
ERV	ERV Total effectiveness (Enthalpy Recovery Ratio)	Addition of ERV/HRV Increase in ERV/HRV effectiveness
HVAC System - VAV Reheat		
ZnMin	VAV Box minimum in percent (all OA at 133% of required)	Dual max VAV box adjustment
VrstSAT	Supply Air Temperature Reset degrees of cooling SAT, deg F	Addition or increase in SAT reset
VrstSP	Is static pressure controlling fan reset (Y or N)	Addition of static pressure fan speed reset
Independent calculations (not in parametric regression model) included in SBC		

Symbol	Input Parameter	Measures that can be modeled in SBC
ExLTf	Factor of Exterior Lighting use vs. typical base	Exterior lighting power Time/photocell control Proximity control
PVwSF	Installed PV w/sf of bldg area	Photovoltaic system installed capacity
SWHf	Factor of SWH use vs. typical base case	Service water temperature setpoints Service water energy recovery Solar water heating Recirculation or trace heat control Tank Insulation Pipe Insulation

Parameter Impact

The relative impact of the range modeled for each parameter was tested in each building type for three climate zones: 2A (warm), 5B (moderate), and 7 (cold) as discussed under "Basis and Methodology." The resulting tornado diagram of energy cost index ($\$/ft^2$, ECI) impact for the retail model in climate zones 2A and 7 are shown in Figures 1 and 2 as examples. The vertical line represents the ECI when all parameters are typical, while the orange bars to the right show increased ECI for the worst case, and green bars to the left show reduced ECI for the best case. ECI is based on $0.1069/kWh and $0.7758/therm. Larger bars that extend beyond the x axis are noted as not to scale (NTS). The tornado diagrams show which parameters have the largest impact on ECI and allow comparison of parameter impact by climate zones. For example, heating efficiency is more important in cold climate zones while cooling efficiency is more important in warm climate zones.

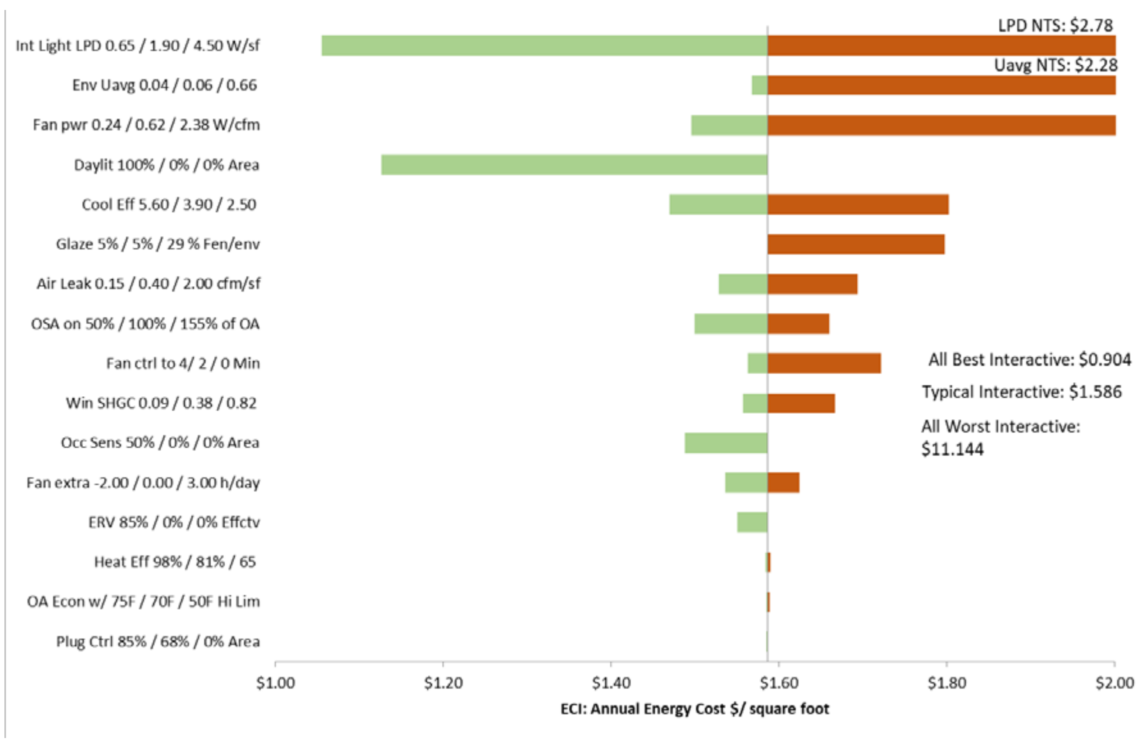

Figure 1:Range of parameter impact for Retail Strip-Mall in warm Climate Zone 2A

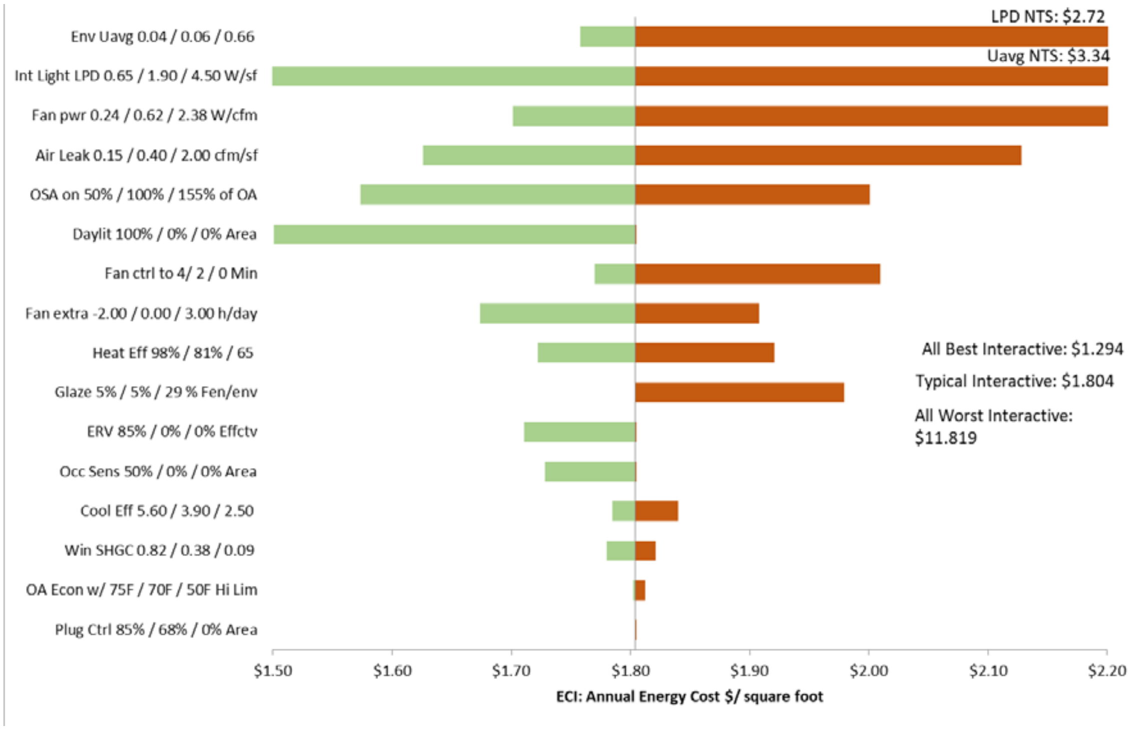

Figure 2:Range of parameter impact for Retail Strip-Mall in cold Climate Zone 7

Basis and Methodology

For the purpose of this work we consider a simple commercial building as:

- A single function building with floor area less than 50,000 square feet,
- with a localized, single HVAC system type, and
- has a relatively simple geometry and building fabric.

SBC development process followed these steps:

- Identify commonly desired efficiency options that affect energy operating cost of each building type.
- Identify ranges of parameters for each efficiency option representing vintage to maximum technical potential.
- Complete sets of interactive building model simulations in EnergyPlus for each prototype building in 16 ASHRAE U.S. climate zones.
- Use the simulation results to develop regressions where the parameter values are independent variables and gas and electric use and cost are dependent variables.
- For validation, re-run a sample of packages with the EnergyPlus simulation model to verify regression accuracy.
- Include regressions in an interactive spreadsheet tool for end use and cost calculation.

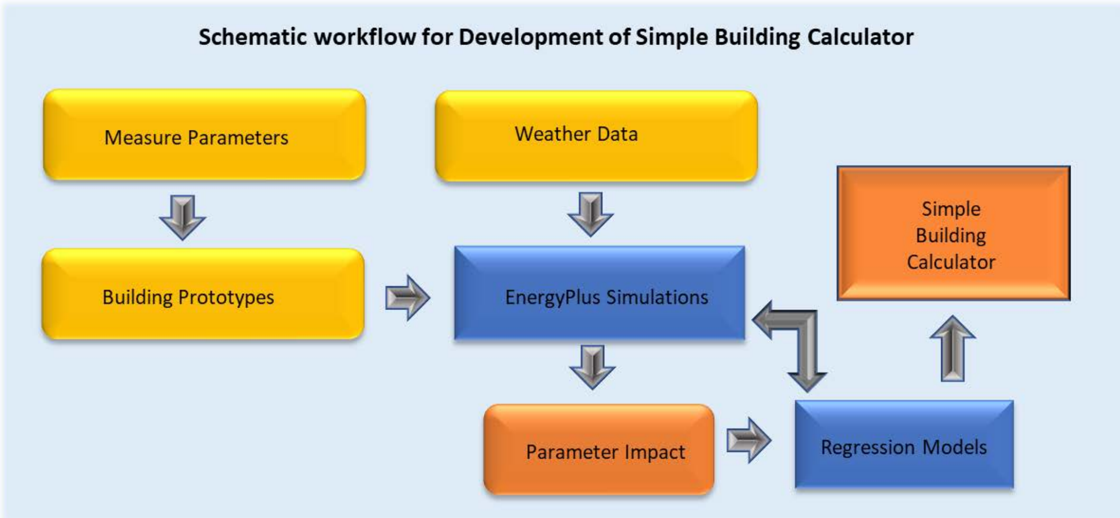

Figure 3: Workflow Schematic for Simple Building Calculator Development

Building Energy Simulations

The simulations were conducted using prototype building models (DOE 2018): Medium Office (Off), Strip mall (Rtl), Midrise Apartment (Apt) and Primary School (Sch). These building types were selected for the beta since they represent a range of simple commercial building functions and are relatively simple and common building types in the U.S. commercial building stock. Pertinent details of the prototype models are provided in Table 2. Simulations were done in EnergyPlus version 9 using a template-based simulation framework described in (EnergyPlus 2018; Thornton et al. 2012). The simulations were performed in a representative city for each of the 16 ASHRAE climate zones.

Table 2: Prototype Description

	Medium Office	**Retail Strip mall**	**Midrise Apartment**	**Primary School**
Area (sq ft)	53,628	22,500	33,741	73,959
Aspect ratio	1.5	4	2.74	1.13
Floor height (ft)	13	17	10	13
No. of floors	3	1	4	1
Weekday Operation	7 am to 12 pm	9 am to 12 pm	1 am to 12 pm	9 am to 9 pm during study periods
Saturday Operation	7 am to 7 pm	12 am to 12 pm	1 am to 12 pm	9 am to 9 pm during summer holidays
Sunday Operation	7 am to 6 pm	12 am to 12 pm	1 am to 12 pm	9 am to 9 pm during summer holidays
Heating*	Gas with zone electric reheat	Gas Furnace	Gas Furnace	Heat Pump
Cooling*	DX	DX	DX	DX
HVAC air distribution *	Variable Volume	Constant Volume	Constant Volume	Constant Volume

DX = Direct Expansion *Additional HVAC system types will be developed

The parameter list was developed for each building type based on judgement of its' potential impact on building energy use and applicability or popularity of related measures in real buildings. The parameter list for each individual building cover measures that impact all major energy end-uses in the building. Individual parameters were then studied to identify efficiency values that represent building characteristics ranging from vintage (below code) to maximum technical potential per present day technology (beyond code). For some items, such as federally mandated equipment efficiency, a reasonable 15 year past code level was the floor. Efficiency values for each individual parameter were classified into 4 to 5 individual levels (Lvl) with Lvl1 representing the least efficient option. Each higher Lvl number represents increments in efficiency improvements. ECMs included in the analysis and inputs for each level of the efficiency are presented in Table 3. For each parameter, a typical case was also identified. The typical case represents efficiency level of a similar building in compliance with requirements of 90.1-2016 energy code. In addition, 38 combination runs were simulated to capture the interactive impacts of each parameter. The combination runs included All parameters at each individual level; Mixes of Envelope, Interior Load, Light or HVAC parameters with other category parameters held constant at baseline level and finally a mix of all parameters at varying level combinations. Details of the energy modeling are provided in Nambiar and Hart (2020) and a high-level summary is provided here.

Table 3: Parameter Inputs by Efficiency Level

Parameter	***Description***	***Bldg.***	***Lvl1***	***Lvl2***	***Lvl3***	***Lvl4***	***Lvl5***	***Typical***
GER[a]	Glazing to envelope ratio (Win Area + Sky Area) / (Wall Area + Roof Area)	Off	48%	25%	19%	6%	19%	19%
		Rtl	29%	27%	9%	5%	*NA*	5%
		Apt	60%	55%	39%	13%	3%	39%
		Sch	24%	19%	17%	10%	5%	19%
U-avg[b]	Envelope heat loss: (∑UA) / A	Off	0.66	0.41	0.17	0.10	0.07	0.10
		Rtl	0.66	0.39	0.11	0.06	0.04	0.06
		Apt	0.60	0.38	0.16	0.09	0.05	0.09
		Sch	0.66	0.39	0.11	0.06	0.04	0.06
Leak	Envelope cfm/sf of envelope area @75pa	All	2	1	0.4	0.15	*NA*	0.4
SHGC	SHGC, including shading adjustments	All	0.82	0.60	0.38	0.22	0.09	0.22
LPD[c]	Interior W/sft	Off	4	2	1	0.66	0.25	0.66
		Rtl	4.5	3.2	1.9	0.95	0.65	1.9
		Apt	1.07	0.86	0.68	0.55	*NA*	0.68
		Sch	1.07	0.86	0.68	0.55	*NA*	0.68
Adl[d]	% of gross floor area with daylight controls	Off	0%	27%	41%	60%	61%	27%
		Rtl	0%	22%	44%	78%	100%	0%
		Apt	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
		Sch	0%	14%	29%	43%	57%	43%
Aos[e]	% of gross floor area with occupancy lighting controls	Off	0%	48%	66%	88%	*NA*	66%
		Rtl	0%	20%	35%	50%	*NA*	0%
		Apt	0%	20%	35%	75%	*NA*	0%
		Sch	0%	27%	59%	86%	*NA*	59%

Parameter	*Description*	*Bldg.*	*Lvl1*	*Lvl2*	*Lvl3*	*Lvl4*	*Lvl5*	*Typical*
ERV[f]	ERV Enthalpy Recovery Ratio	All	0%	10%	50%	70%	85%	0%
CoolCOP	Cooling Nominal COP (efficiency)	All	2.5	3.0	3.9	5.6	*NA*	3.9
HeatEt	Heating Efficiency (Et or HSPF)	All	0.65	0.75	0.81	0.98	*NA*	0.81
FanPwr[g]	Total Fan power in W/cfm	Off	2.01	0.91	0.53	0.21	*NA*	0.53
		Rtl	2.38	1.49	0.62	0.24	*NA*	0.62
		Apt	1.81	1.07	0.48	0.19	*NA*	0.48
		Sch	2.96	1.37	0.78	0.3	*NA*	0.78
FanCtrl	VAV Fan % turndown minimum	Off	100%	66%	50%	15%	*NA*	50%
	Fan Control Type	Rtl, Apt, Sch	CV	Cycle	2-speed	3-speed	VAV	2-speed, Cycle, 2-speed
Econ	OA Econo high limit lockout temperature, DB (°F)	Non-Apt	50F	60F	65F	70F	75F	70F
		Apt	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
OSA	Average annual % of 62.1 Design Outside air, occupied (includes DCV adjustments)	Off	200%	133%	118%	100%	50%	133%
		Rtl	133%	118%	100%	50%	*NA*	100%
		Apt	155%	120%	100%	75%	50%	100%
		Sch	155%	125%	100%	75%	50%	75%
APlug[h]	% of gross floor area with 50% plug load control (W/ft^2 in Apt)	Non-Apt	0%	34%	68%	85%	*NA*	68%
		Apt	1.50	1.2	0.75	0.5	*NA*	0.75
VrstSAT[i]	SAT reset, deg F	Off	0	5	5	10	10	5
VrstSP[j]	Fan Static Pressure reset	Off	N	N	Y	N	Y	Y
ZnMin	VAV Box minimum in percent of supply air	Off	50%	40%	30%	20%	5%	30%
FanExtra	Extra hours (warmup and unoccupied) fan is ON and OA damper OPEN Mon-Sat	All	3	2	1	0	-2	0

Table notes:

a. Glazing to Envelope Ratio (GER) is calculated as:

$$\frac{(\text{Window Area} + \text{Skylight Area})}{(\text{Gross Wall Area} + \text{Gross Roof Area})}$$

For example, in the Office prototype GER at Lvl 1 and Lv2 modeled at 48% and 25% respectively has a combination of windows and skylights as shown below:

Off GER	*Lvl1*	*Lvl2*
GER	48%	25%
Win Area	90% of Wall Area	48% of Wall Area
Sky Area	3% of Roof Area	0% of Roof Area

b. Envelope Heat Loss (U-avg) is calculated as:

$$\frac{\sum(Uw * Aw) + \sum(Ur * Ar) + \sum(Uf * Af)}{\sum Aw + \sum Ar + \sum Af}$$

Where: Uw = U-factor of opaque walls in Btu/ft^{2}-F-hr,
Aw = Area of opaque walls in ft^2,
Ur = U-factor of roof in Btu/ft^{2}-F-hr,
Ar = Area of roof in ft^2,
Uf = U-factor of fenestration in Btu/ft^{2}-F-hr,
Af = Area of fenestration in ft^2.

c. Lighting Power Density (LPD) in the Office and School models are assumed from ambient light sources, in the Retail model as ambient and display lights and in the Apartment model as a combination of hard-wired and plug-in lights.

d. Daylight Controls (Adl) is modeled for various scenarios of daylight availability in a space ranging from no daylight controls to maximum due to presence of windows and skylights capable of daylighting the entire space in the model.

e. Occupancy Lighting Controls (Aos) Space types considered for this measure and estimated savings from occupancy sensors in each space type are shown below. Modeled lighting schedules were adjusted to reflect these savings estimates (VonNeida, Maniccia, and Tweed 2001).

Space Type	*Est. Savings*	*Space type*	*Est. Savings*
Office-open plan	35%	*Storage*	60%
Office-enclosed	38%	*Lounge*	15%
Corridor	55%	*Dining*	15%
Conference	44%	*Classroom*	43%
Stairway	15%	*Retail*	15%
Restrooms	60%		

f. ERV Enthalpy recovery ratio (ERR) is modeled by changing the heat exchanger sensible and latent effectiveness and the associated fan energy modeled as the wheel parasitic power as shown in example below. Lvl 1 with 0% effectiveness represents a scenario with no heat or energy recovery.

ERV	*Lvl1*	*Lvl3*	*Lvl5*
ERV ERR	0%	50%	85%
Sensible effectiveness	0%	67%	91%
Latent effectiveness	0%	36%	90%
Fan Power (W/cfm)	0	0.41	0.55

g. Fan Power (FanPwr) is calculated as:

$$FanPwr, W/cfm = \frac{FanSP * 745.7}{FanME * FanCF * 6387}$$

where,
FanSP is fan total static pressure in inches of H_2O,
FanME is Fan motor efficiency
FanCF is Fan mechanical efficiency

h. Plug Load Reduction (Plug) measure includes strategies for reducing plug load consumption in buildings. For Office, Retail and school buildings we assumed that at least 50% of all 125 volt 15- and 20- ampere receptacles installed in private offices, open offices, conference rooms, breakrooms, individual workstations and classrooms will have controlled receptacles capable of turning the receptacle power off during unoccupied hours or when no occupants have been detected for more than 20 minutes. For apartments this measure represents reduction in plug load use with energy efficient equipment.

i. VAV VrstSAT is the supply air temperature (F) reset range and is modeled vs. outside air.

j. VAV VrstSP, fan static pressure reset is expressed as a Boolean (0-No, 1-Yes) and is modeled by changing the fan power coefficient inputs.

Major Findings from Simulations

The parameters that resulted in highest building ECI when compared to the typical case across the three climate zones reviewed were Envelope heat-loss and Interior Lighting Power Density, likely because worst case vintage buildings were included. Envelope heat-loss and Interior Lighting Power Density were also the top two parameters that resulted in the widest range of building energy cost in modeled building types. Parameters that show potential for the lowest building energy cost varied by building type and climate zone. In the Office models, the Zone Minimum measure parameters resulted in least building energy cost in the cold and mild climate zones. Higher efficiency levels in the Interior Lighting Power Density and Cooling Equipment Efficiency measures resulted in lowest building energy costs in the mild and warm climate zones. In the Retail models, higher efficiencies in Air leakage and Heating Equipment Efficiency resulted in least ECI in cold climates and Lighting Power Density and Daylighting Control measures resulted in least ECI's in both mild and warm climates.

Regression Development

The EnergyPlus results were used to develop regressions where the parameter values are independent variables and gas and electric use are dependent variables, with the following rules.

- Separate regression coefficient sets are developed for each HVAC system type in each climate zone.
- Separate regression equations are developed for each energy type with some separation by end use: general electric; cooling, auxiliary HVAC electric; electric or gas heat; and other gas are all separate regression equations. This was found necessary to maintain significance and keep results comparative between different heating types.
- All option parameters are retained as independent variables in at least one of the energy type equations, even if their significance is low.
- In regressions for the non-primary energy type (e.g., the gas interaction with lighting), insignificant variables are dropped.
- Interactive variables or second- and third-order variables are included where there is a logical justification and they improve either the R-correlation or overall building regression projections compared to the simulated results.

Acknowledgment, Conclusion and Next steps

The authors would like to thank the Department of Energy for funding this project. We would also like to thank PNNL researchers Linda Sandahl, Michael Rosenberg and Dongsu Kim for their technical contributions and support.

In conclusion, the Simple Building Calculator gives program planners, researchers, and building designers an option for interactive data-driven decision making without the high upfront cost of custom BEM modeling. It makes interactive savings calculations of building and climate specific efficiency measures or measure packages readily and quickly available for small commercial buildings. With the beta version of the SBC tool we were able to test the underlying concept and develop the simulation and regression methodologies required for the tool development. Next steps include:

- Expansion of simulation and regression framework to include more building types, including: Office, Retail, School, Apartment, Warehouse, and Restaurant. After initial deployment, the building types could be further expanded.
- Expansion of simulation and regression framework to include more HVAC system types, including where appropriate: Single zone heat pump, single zone air condition with gas heat, VAV with electric and hydronic reheat, water source heat pump and variable refrigerant flow heat pump.
- Stakeholder review of tool interface and output formats with responsive updates.
- Validation of regression models and results, and accuracy documentation,
- Stakeholder field validation of a revised tool.

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