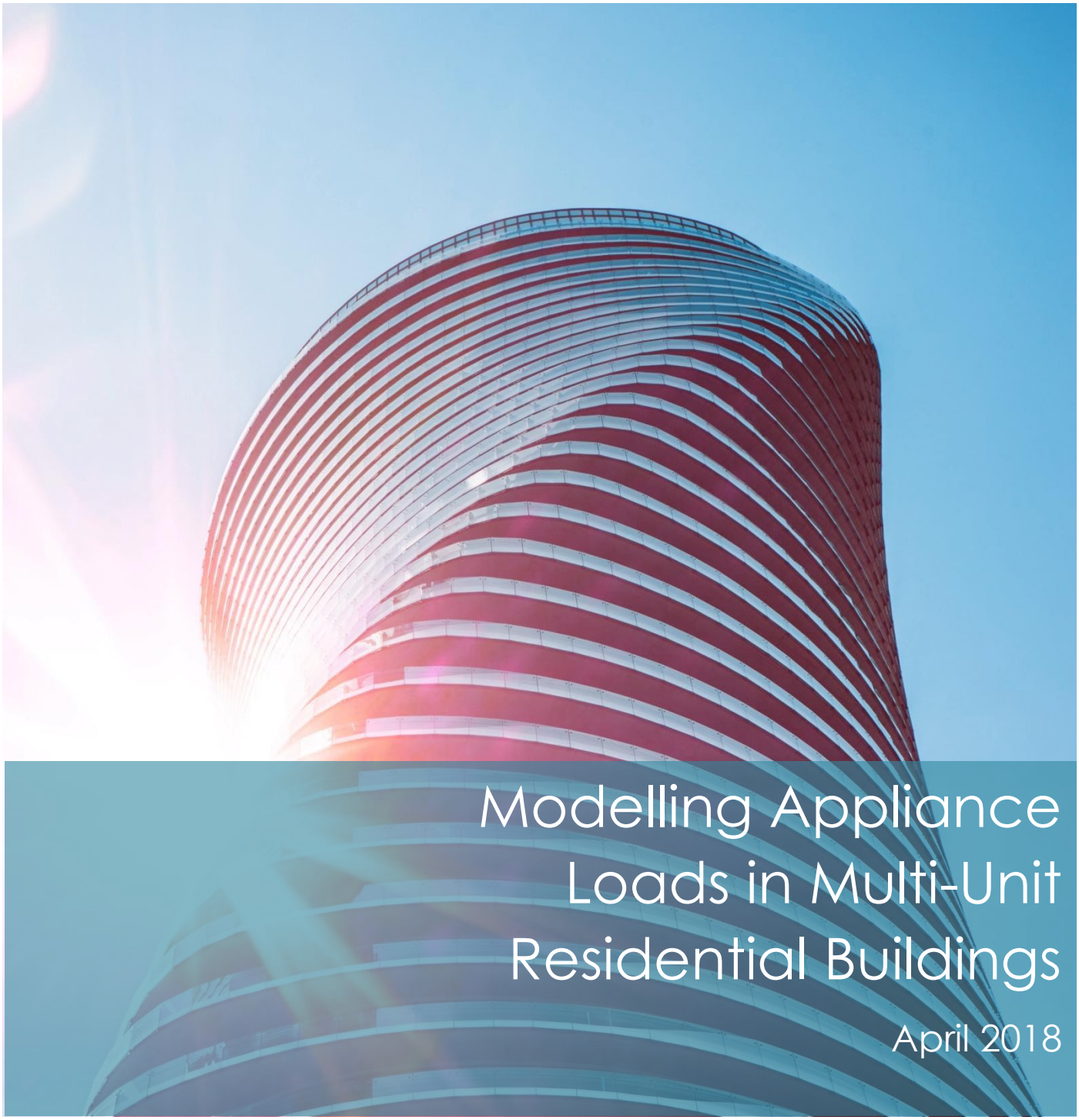

Modelling Appliance Loads in Multi-Unit Residential Buildings

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Prepared by: Pratus

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Contents

1. INTRODUCTION

Fundamental regulations for energy modelling are found in energy codes such as ASHRAE 90.1 and in the Building Code through SB-10 in Ontario. Municipalities, third party rating systems, and utility companies that have their own energy programs frequently issue modelling guidelines or terms of reference to ensure incentive applicants are submitting comparable and high-quality energy modeling documents. Over the years the building simulation industry has evolved, and so have the guidelines that govern it. However, the subject of unregulated loads, has continued to be excluded from these guidelines.

With the increased stringency of updated energy codes and regulations, consumption on a total building energy level has successfully been reduced. In large part the success of this reduction is a result of advances in lighting, HVAC and building envelope components. The wide-scale availability of high efficiency options of these building components has decreased the energy associated with those regulated end uses. As a result, the unregulated portion of a building's load now has a greater impact on energy performance than before and thus requires further investigation. One building type of which unregulated loads have a significant impact on their energy consumption is the Multi Unit Residential Building (MURB). For these building types, energy associated with in-suite appliances, typically consisting of refrigerators, dishwashers, ovens, stoves, washers, and dryers represents an ever more significant portion of the total building energy consumption as the other, traditionally energy intensive end-uses, shrink.

Current guidelines for modelling in-suite appliances and allowing credit for energy efficient appliances vary. Sustainable Buildings Canada, which is responsible for delivering the Savings

by Design incentive program, is interested in exploring how appliance energy is treated by other programs and what the appropriate Equipment Power Density (EPD) is for the Savings by Design program.

2. RESOURCE REVIEW

Kitchen appliances are classified as un-regulated energy end-uses. Regulated energy uses include those addressed by standard energy codes such as ASHRAE 90.1 and usually comprise space heating, space cooling, ventilation, lighting, service water heating, motors and a few other end-uses. Un-regulated energy uses are those which are not addressed by the standards and may include kitchen appliances, elevators, televisions, computers and many others.

Different municipalities, such as the City of Toronto and Vancouver, and Local Distribution Companies (LDCs), have established positions on allowing credit for high efficiency appliances through their CDM programs. Although different in their delivery, a similarity throughout is the use of the ENERGY STAR rating as a reference.

Canada's ENERGY STAR Simple Savings Calculator v12.1[1] (December 2017) is designed to show those procuring large volumes of appliances the direct benefit of purchasing ENERGY STAR appliances. The spreadsheet allows users to compare non- ENERGY STAR Certified appliances with various ENERGY STAR products. This is an appropriate tool for those selecting equipment for MURBs as it provides both a reference energy use for non-ENERGY STAR appliances and allows the user to compare several ENERGY STAR certified models against one another. No guidance is provided on how the loads relate to sensible and latent gain.

US ENERGY STAR Modelling Guide for Multifamily High-Rise Program [2](December 2017) is a document developed for the US programs and has established baseline values that are significantly lower than the values provided by Canada's ENERGY STAR Simple Savings Calculator. For example, this document assigns 164 kWh/year as the annual energy usage for ENERGY STAR dishwasher unit compared to the 270 kWh/year threshold from the Canada's ENERGY STAR Simple Savings Calculator. The guide allows for the modellers to take credit for ENERGY STAR appliances. The guide does not provide a prescriptive schedule to be used for in-suite appliances but instead references other resources such as Table N2-3 of California's 2005 *Non-residential* ACM Manual. The values are provided in a total annual consumption per unit as well as a breakdown of latent and sensible load to the suite, from each appliance.

BC Hydro Energy Modelling Guide[3] (March 2016) provides a W/ft^2 value to use for modelling in-suite appliances, and a prescriptive schedule to be used in all models. The schedule and power density are based on Building America Research Benchmark published by NREL. Under the BC Hydro incentive framework, credit is not given for the energy savings resulting from ENERGY STAR appliances. The EPD value for suites, including appliances, is 7.2 W/m^2. based on an average dwelling size of 850 ft^2 and the annual full load hours for the schedule provided equal 5,767 hours. The guide also provides a breakdown of the sensible and latent loads

[1] http://oee.nrcan.gc.ca/residential/business/energystar/procurement/calculator.cfm

[2]https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/mfhr/ENERGY_STAR_MFHR_Simulation_Guidelines_AppG2016.pdf?4724-c6be

[3] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/power-smart/builders-developers/energy-modeling-guidelines.pdf

associated with the 7.2 W/m^2 appliance load, which is 62% sensible and 11% latent load; the balance of the load within the space is vented to outdoors.

City of Vancouver Energy Modelling Guidelines Version 1.0[4] (March 2017), which applies to building covered by Vancouver's Buildings Policy including low-rise and high-rise residential, recommends a 5 W/ft^2. value for in-suite plug loads that includes refrigerators, dishwashers, dryers, and other small appliances within a typical dwelling. Credit for ENERGY STAR appliances that consume less energy than the rating threshold is allowed. In other words, the baseline assumes ENERGY STAR appliances are included. If there is data available that indicates installed ENERGY STAR appliances consume less than the rating threshold, credit can be taken. This credit is accounted for by proportionally decreasing the 5 W/ft^2. value based on an appliance kWh rating relative to the ENERGY STAR requirements for that appliance. For example:

ENERGY STAR minimum kWh ratings for suite appliances: 2,000 kWh
Project's energy use for selected in-suite appliances: 1,780 kWh
Reduction in plug load = 5 W/m^2 x 1,780/2000 = 4.45 W/m^2

The suggested NECB 2011 schedules for receptacles are equivalent to 3,869 full load hours per year. No guidance is provided on how the loads relate to sensible and latent gain. NECB 2015 uses the same schedules as NECB 2011.

Building Americas House Simulation Protocols[5] **(2014)** provides detailed information on the load profiles of individual kitchen appliance, such as refrigerators, as well as a combined load profile for all typical home appliances. The document is also associated with a detailed spreadsheet allowing the user to calculate the energy savings associated with efficient refrigerators, clothes washers, dishwashers, and dryers. The reference case energy consumption for the appliances is based on the Building America B10 Benchmark for single-family low-rise residential buildings which is based on the 2009 International Energy Conservation Code (IECC) code. The values vary from the numbers published by ENERGY STAR for typical annual energy consumption for appliances. Sensible and latent load fractions are provided for each appliance within the document. Low-rise occupancy varies significantly from high-rise. Low-rise residential dwellings tend to have a larger finished floor area than high-rise residences. As a result, the same appliances within the dwelling will have a higher associated W/ft^2 for high-rise units as opposed to the lower W/ft^2 associated with low-rise due to the variance in floor area.

[4] http://vancouver.ca/files/cov/energy-modelling-guidelines-v1.0.pdf
[5] https://www.nrel.gov/docs/fy14osti/60988.pdf

3. RECOMMENDATIONS

Important factors include not only the type of appliances (i.e. refrigerator, dishwasher, etc.) but the sub-type as this affects the energy use significantly. For example, standard ENERGY STAR dishwashers must consume less than 307 kWh/year to qualify whereas compact ENERGY STAR dishwashers must meet a 222 kWh/year requirement, a 27% reduction. Some modern multi-unit residential units have opted to purchase compact appliances and this fact should be considered when modelling the EPD.

The location of the laundry facilities is also an important factor for in-suite appliance energy modelling. Most condominium and a large portion of high-end rental units have in-suite laundry. The other arrangement that is more common in rental apartments is to have a central laundry facility which will use commercial grade appliances, sometimes with coins or other forms of payment required in order to be used. Both scenarios are discussed below.

3.1 What is the reference

The baseline case or reference building EPD varies across the different documents addressing equipment power density for appliances. Currently, the Ontario Building Code does not address kitchen appliances. Most of the resources reviewed in this report allow credit for ENERGY STAR appliances, which indicates that the standard industry practice is to select non-ENERGY STAR rated appliances and that installing ENERGY STAR appliances is a performance improvement measure.

It is recommended that the Canada's ENERGY STAR Simple Savings Calculator (v12.1) be used to establish the reference for non- ENERGY STAR rated appliances for MURB models. At time of writing, this is the most current and relevant document addressing the energy use of common appliances. Where the Simple Saving Calculator does not provide a value, such as for cooking ranges and miscellaneous non-appliance loads within the suite, the US ENERGY STAR MFHR Simulation Guidelines should be used.

3.2 W/ft^2 or per appliance?

The W/ft^2 method of inputting appliance load is the simplest to implement, although some accuracy is lost. For example, different suite sizes may result in a smaller or larger W/ft^2 number than is realistic for the specific building. A building with larger suites will have a lower EPD and a building with small suites will have a higher EPD with the same appliances selections. The more detail provided in the development of the receptacle load model, the more accurate the results from the model will be. It is important to establish the total number of suites within a MURB, and the total number of appliances, and their make to accurately determine the appliance load.

At an early stage in the design process when appliances may not be selected, a default W/ft^2 number for the appliance EPD will be the most appropriate approach. Values are recommended in section 3.4 of this document. As the ENERGY STAR rating is evolving to remain current, the threshold for ENERGY STAR qualification may change between initial

design and project completion. It is recommended the reference point for the threshold is taken from the date that appliances are ordered.

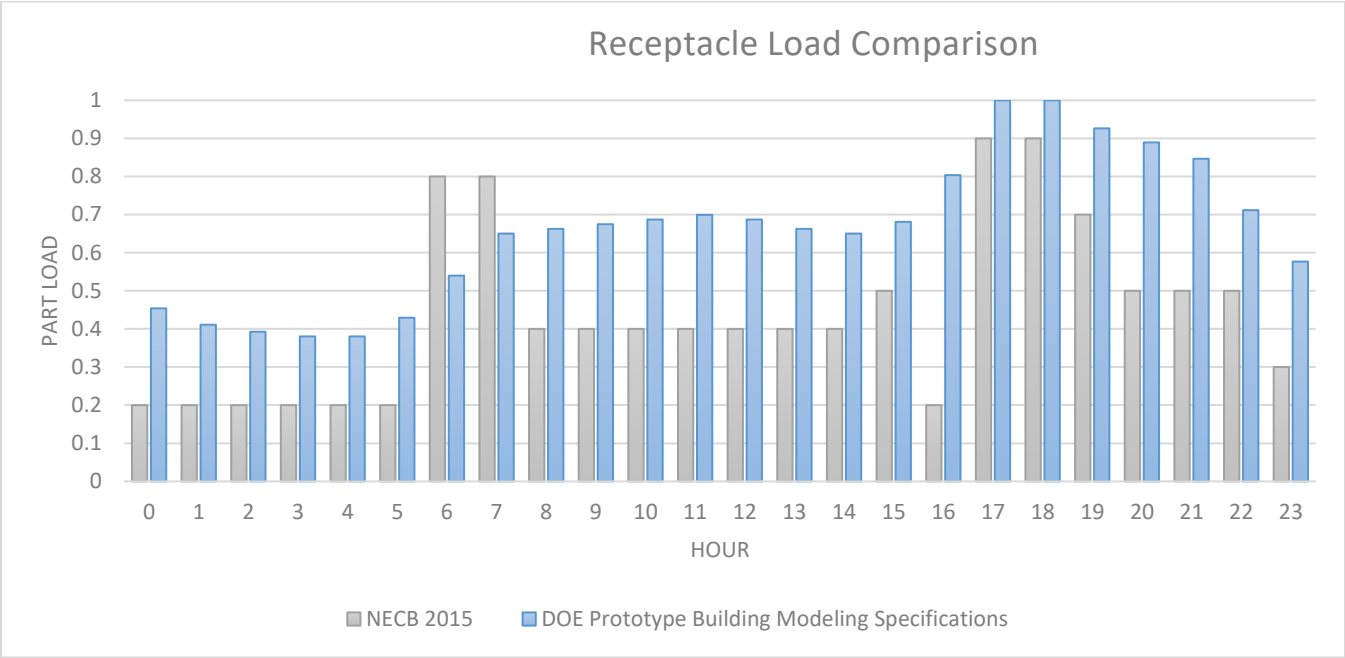

Figure 1: Receptacle Load Schedule Comparison

3.3 Schedules

NECB 2015 schedules are commonly used for MURBs. The 2015 equipment load schedule for residential space types equates to 3,869 full load hours per year. This schedule should be used in conjunction with the individual appliance kWh/year rating to develop an appropriate peak load to use within the model.

If using a different schedule, the total peak load should be modified to ensure the same total annual consumption. Using the same peak load with different schedules results in a different annual energy use that may not align with the annual rated energy of the ENERGY STAR appliances. Figure 1 shows two different schedules, with the NECB 2015 schedule having 3,869 full load hours and the DOE prototype having 5,766 full load hours annually. The DOE prototype schedules are used in the BC Hydro Energy Modelling Guide as well as Building Americas House Simulation Protocols.

3.4 At Schematic Design

3.4.1 Units with In-Suite Laundry

At schematic design when appliance selections are not available a W/ft^2 EPD, assuming average suite size and typical appliances should be used. Using the Canada's ENERGY STAR Simple Savings Calculator (v12.1) and an average suite size of 850 ft^2, the peak EPD is 0.99 W/ft^2 for the reference, non-ENERGY STAR Appliance case, with 0.64 sensible and 0.11 latent load fraction. For the ENERGY STAR proposed case, the peak EPD is 0.92 W/ft^2 with 0.63 sensible and 0.11 latent load fraction. This number is conservative and assumes the ENERGY STAR

appliances are at the maximum kWh/year rating to meet ENERGY STAR qualification, and no better. It is worth noting that although there is a 15% energy reduction in the ENERGY STAR qualified appliances, overall this only translates to a 7% reduction in overall suite EPD. Ranges, which do not have an ENERGY STAR rating, and other in-suite appliances such as TVs, computers, gaming system and the like are kept constant.

These values are appropriate for all suite spaces within the energy model.

Annual Appliance and Equipment Loads for MURB (in-suite laundry)

Appliance	Sensible Load Fraction	Latent Load Fraction	Apartment Electricity (kWh/yr)	ENERGY STAR Apartment Electricity (kWh/yr)
Refrigerator (1)	1	0	529	476.1
Clothes Washer (standard) (2)	0.8	0	287	173
Clothes Dryer (Electric) (3)	0.15	0.05	641	608
Dishwasher (standard) (4)	0.6	0.15	307	270
Range (Electric) (5)	0.4	0.3	604	604
Variable Miscellaneous Electric Loads (6)	0.9	0.1	892.5	892.5
		Total kWh/yr	3260.5	3023.6
		Daily Peak watts/ft²	0.99	0.92
		Sensible Load Fraction	0.64	0.63
		Latent Load Fraction	0.11	0.11

FFA: finished floor area, ft²	850

(1) Bottom-mount freezer without through the door ice from Canada's ENERGY STAR Simple Savings Calculator (v12.1)
(2) Standard top-loading clothes washer from Canada's ENERGY STAR Simple Savings Calculator (v12.1)
(3) Standard 240V clothes dryer from Canada's ENERGY STAR Simple Savings Calculator (v12.1)
(4) Standard dishwasher from Canada's ENERGY STAR Simple Savings Calculator (v12.1)
(5) ENERGY STAR MHRP Simulation Guidelines Version 1.0 December 2017
(6) ENERGY STAR MHRP Simulation Guidelines Version 1.0 December 2017 1.05 kWh/FFA for miscellaneous unit plug loads such as computers, televisions, printers, etc.

3.4.2 Units with Common Laundry

Buildings that have a common laundry area will not have in-suite clothes washers and dryers. This energy can be removed from the calculation in Section 3.4.1. This results in a peak EPD of 0.71 W/ft² for the reference, non-ENERGY STAR Appliance case, with 0.75 sensible and 0.14 latent load fraction. For the ENERGY STAR proposed case, the peak EPD is 0.68 W/ft² with 0.75 sensible and 0.14 latent load fraction.

Annual Appliance and Equipment Loads for MURB (common laundry)

Appliance	Sensible Load Fraction	Latent Load Fraction	Apartment Electricity (kWh/yr)	ENERGY STAR Apartment Electricity (kWh/yr)
Refrigerator (1)	1	0	529	476.1
Dishwasher (standard) (2)	0.6	0.15	307	270
Range (Electric) (3)	0.4	0.3	604	604
Variable Miscellaneous Electric Loads (4)	0.9	0.1	892.5	892.5
		Total kWh/yr	2332.5	2242.6
		Daily Peak watts/ft²	0.71	0.68
		Sensible Load Fraction	0.75	0.75
		Latent Load Fraction	0.14	0.14
		FFA: finished floor area, ft²		850

(1) Bottom-mount freezer without through the door ice from Canada's ENERGY STAR Simple Savings calculator (v12.1)
(2) Standard dishwasher from Canada's ENERGY STAR Simple Savings Calculator (v12.1)
(3) ENERGY STAR MHRP Simulation Guidelines Version 1.0 December 2017
(4) ENERGY STAR MHRP Simulation Guidelines Version 1.0 December 2017 1.05 kWh/FFA for miscellaneous unit plug loads such as computers, televisions, printers, etc.

The washer and dryer energy use needs to be allocated to the appropriate zone in the energy model. The annual energy consumption should be calculated using Canada's ENERGY STAR Simple Savings Calculator (v12.1), which provides annual energy use for commercial laundry equipment for MURBS. The energy use in the calculator is provided as a total annual number and can be converted to a peak using the same NECB 2011/2015 schedule.

(Please insert the relevant figures in the grey boxes.)	Non-ENERGY STAR Unit	ENERGY STAR 1	ENERGY STAR 2	ENERGY STAR 3
Type of unit	Front-loading			
Building hot water fuel type	Natural Gas			
Dryer fuel type	Electric			
Facility type	Multifamily			
Number of units	1	1	1	1
Rated unit electricity consumption (kWh/y)	763	307	0	0
Dryer energy (kWh/y)	1,640	1,439	0	0
Combined low-power mode energy (kWh/y)	0	0	0	0
Capacity of washer (cu.ft.)	2.8	2.8	2.8	2.8
Capacity of washer (litres)*	79.3	79.3	79.3	79.3
Incremental cost over Non-ENERGY STAR unit		$200	$0	$0
Assumed product lifetime (years)	11	11	11	11

Figure 2: Canada's ENERGY STAR Simple Savings Calculator (v12.1) Commercial Laundry Equipment

A sample calculation using a 1000 ft² laundry area and 10 laundry pairs is provided below. This table should be modified based on actual laundry room area and number of units for the specific building.

Annual Appliance and Equipment Loads for MURB (common laundry)

Appliance	Sensible Load Fraction	Latent Load Fraction	Electricity (kWh/yr)	ENERGY STAR Electricity (kWh/yr)
Clothes Washer (2)	0.8	0	7630	3070
Clothes Dryer (Electric) (2)	0.15	0.05	16400	14390
		Total kWh/yr	24030.0	17460.0
		Daily Peak watts/ft²	6.21	4.51
		Sensible Load Fraction	0.36	0.26
		Latent Load Fraction	0.03	0.04

Laundry Area, ft²	1000

(2) Standard top-loading clothes washer from Canada's ENERGY STAR Simple Savings Calculator (v12.1)

3.5 At Detailed Design

Once appliance selections are available, further refinement of the energy model can be conducted. Should ENERGY STAR appliances have been specified, additional credit can be taken. An important consideration is that ENERGY STAR rated appliances only ensure that the appliance meets the maximum threshold for the annual consumption, the actual energy consumption varies from model to model. For example, looking at the ENERGY STAR dishwashers available, there are several models which have a lower rated annual consumption than the ENERGY STAR 270 kWh/year. For the Samsung - DW60M99 dishwasher, the rated annual consumption is 239 kWh/year, an 11% reduction over the ENERGY STAR threshold. The table in Section 3.4 can be used to calculate the actual proposed building EPD based on the rated energy of the appliance models.

4. eQUEST INPUT

4.1 Equipment Load Input

Within eQuest, the internal loads, including receptacle/appliance loads, occupant, lighting and miscellaneous loads are entered under the 'Internal Loads' tab which can be seen highlighted in Figure 3.

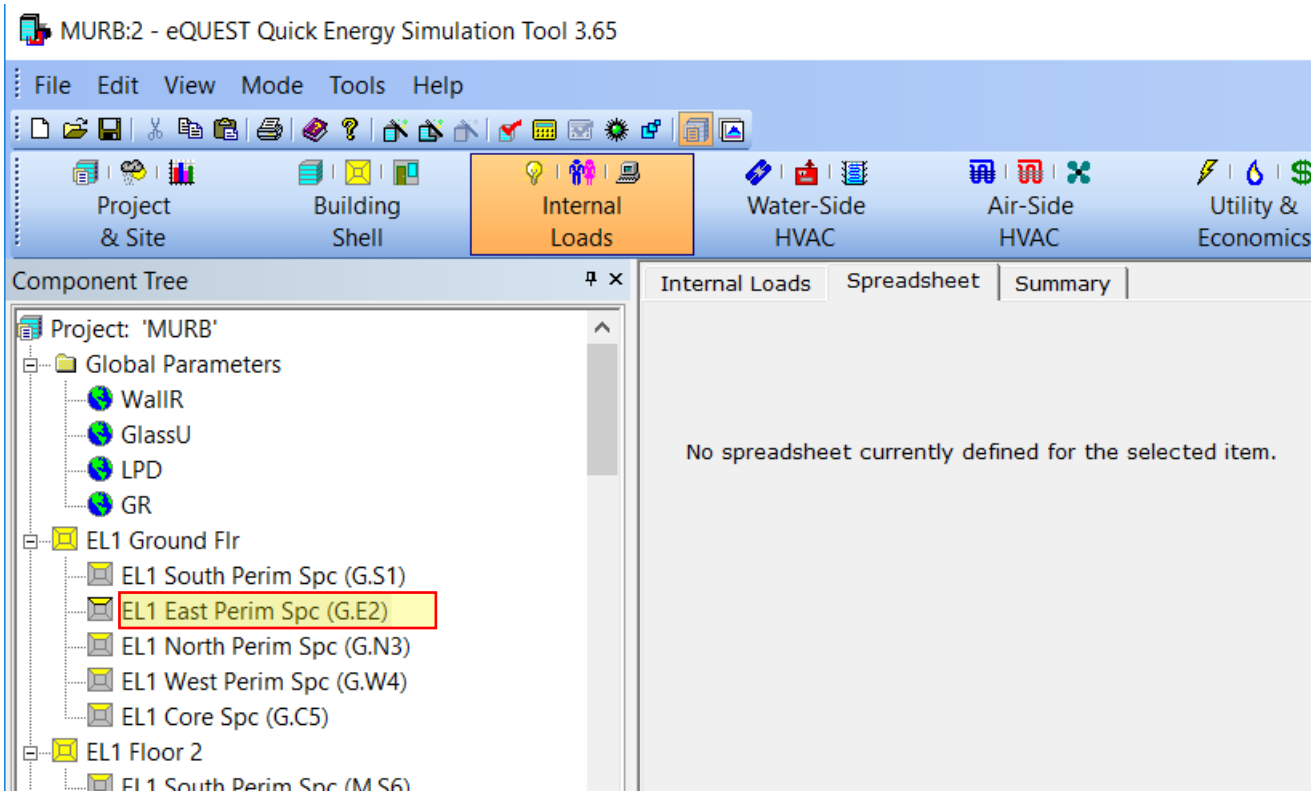

Figure 3: eQuest Internal Loads

Under the 'Internal Loads' tab, the user can navigate to each space to enter the EPD. The in-suite EPD should only be entered in the suite space within the model, and the model should be zoned appropriately to allow for this. By double-clicking the space to be modified, a space properties window is opened. In this example, the highlighted space is selected.

Within this window, several tabs are available for modification. For this exercise the 'Equipment' tab is the relevant one for assigning appliance and receptacle loads for the suite space.

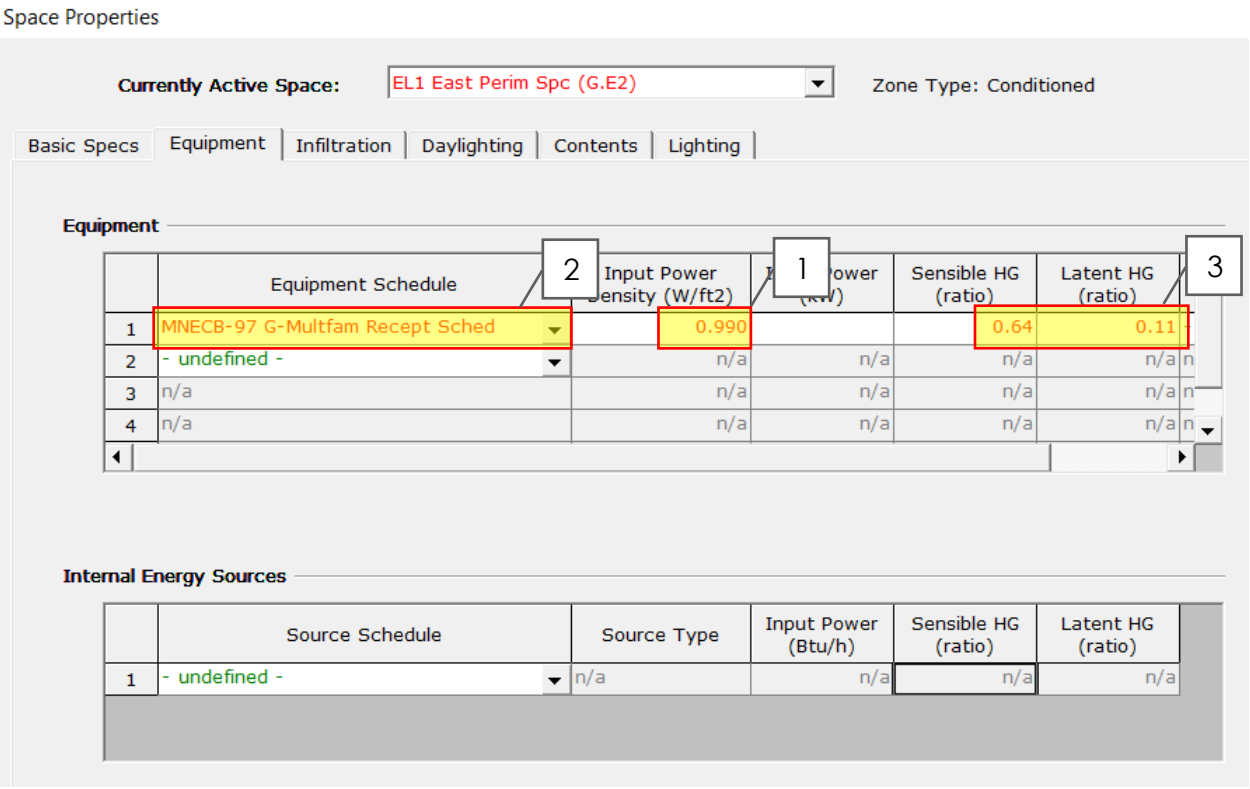

Figure 4: Space Internal Loads

Within the 'Equipment' tab, the user can enter the EPD as either a W/ft^2 or an absolute kW number for the space. As per the recommendation in section 3.4 of this document, the value should be entered as W/ft^2 using either the default value or the calculated value based on actual appliances selected.

In Figure 4, highlighted section:[1] indicates where the EPD should be entered and highlighted section [2] indicates where the appropriate selection of the schedule should be made. In this case, NECB 2011/MNECB 1997 receptacle schedule G is selected in line with the recommendations in section 3.4. Highlighted section [3] indicates where the sensible and latent gain fractions should be entered.

Alternatively, the inputs can be made in the spreadsheet mode of the software. Under the same 'Internal Loads' section, the user can select the 'Spreadsheet' tab highlighted in section [1] of in Figure 5, to view all the space inputs at the same time. To edit the EPDs, the 'Equipment' must be selected from the drop-down menu, as shown in highlighted section [2]. Once in this view, the user can enter the values and schedules as per the previous example and edit and view the attributes of multiple spaces at the same time.

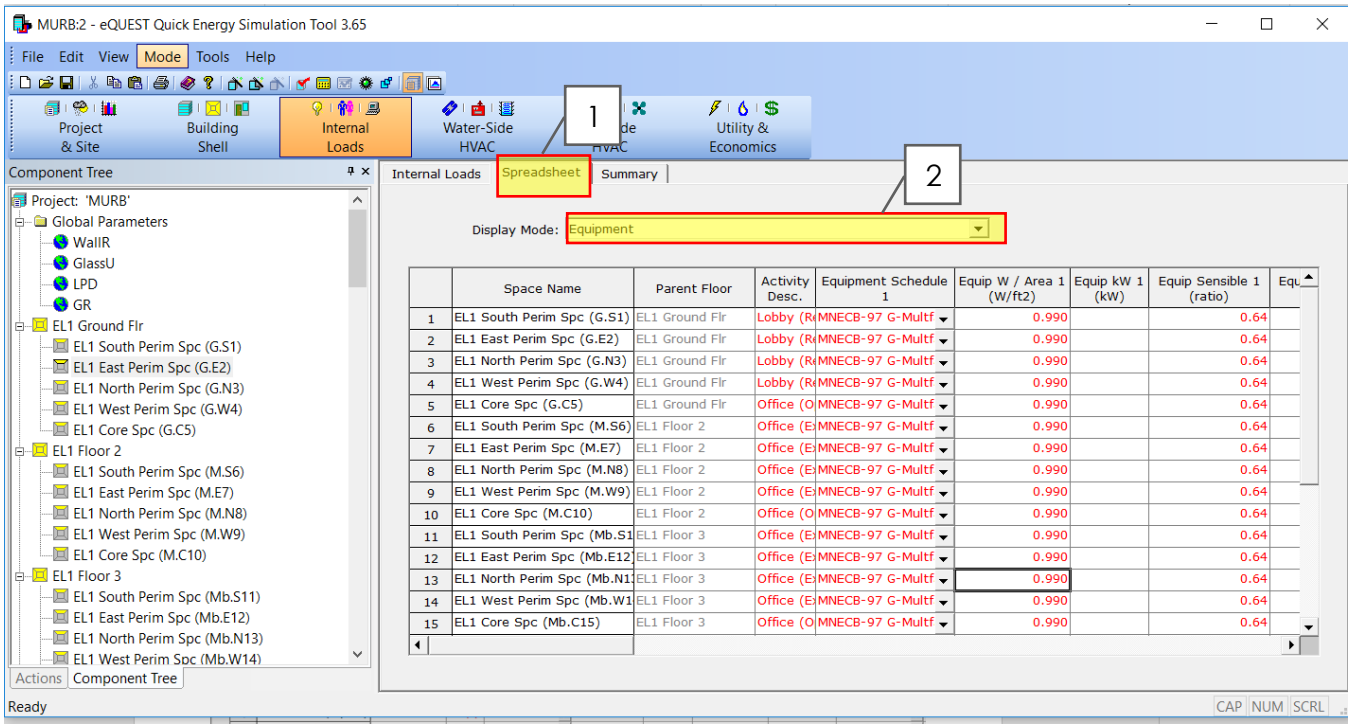

Figure 5: eQuest Internal Loads Spreadsheet View

5. CONCLUSION

Unregulated loads, specifically appliance energy, are an important part of the total energy consumption of a Multi-Unit Residential Building. Modelling appliance energy consumption in an accurate way is necessary in building a representative energy model. It is appropriate to claim credit for specifying and installing ENERGY STAR appliances in MURBs.

Credit within a building energy simulation for ENERGY STAR appliances for suites with in-suite laundry can be taken by modelling a 0.99 W/ft^2 EPD within the reference model and 0.92 W/ft^2 EPD within the proposed model, with appropriate sensible and latent fractions assigned. For units with common laundry, 0.71 W/ft^2 for reference and 0.68 W/ft^2 for proposed should be used with the appropriate energy for commercial laundry assigned to the zone with the laundry machines. Energy for commercial laundry machines can be calculated using Canada's ENERGY STAR Simple Savings Calculator (v12.1).

When final appliance model selections have been made, the energy model should be revised to include actual W/ft^2 values. This should be calculated using the rated kWh/year of the appliances allowing a lower EPD to be included in the proposed building.

References

1. "2014 Building America House Simulation Protocols". National Renewable Energy Laboratory, March 2014.
2. "New Construction Program's Energy modelling guideline". BC Hydro, March 2016.
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4. "ENERGY STAR Multifamily High Rise Program Simulation Guidelines-Appendix G 90.1-2016 Version 1.0". ENERGY STAR, December 2017.
5. "Energy Modelling Guidelines Version 1.0". City of Vancouver, March 2017.
6. "Canada's ENERGY STAR Simple Savings Calculator v12.1", Natural Resources Canada, December 2017.