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Subject: **Phase Two: Summary of Sensitivity Analysis and Updated Modeling Results**

Date: July 27, 2020

Purpose

This document summarizes findings from the sensitivity analysis and preliminary modeling changes to previous analysis results (Phase One Analysis) for Commercial and Residential building prototypes. The results described here are characterized as Phase Two of this project to determine commercial and residential baseline energy use in 2006 as a starting point for analysis of progress toward 2030 building performance mandates. This memo describes the methods and assumptions used in the sensitivity analysis and preliminary results from updating a subset of building types based on research and sensitivity analysis findings.

Commercial Sector Sensitivity Analysis

The preliminary results presented here represent work completed on the analysis plan submitted by Ecotope on June 1st, 2020. Ecotope submitted a description of research findings and analysis plan. The research included analysis of the impact of changes to unregulated loads, lighting power densities, window to wall ratios, and HVAC equipment and operations characteristics on estimated energy use for the 2006 WSEC baseline building stock. Research findings were used to created ranges for different modeling inputs and sensitivity analysis was then used to determine how those ranges impact the overall EUI for each building type. The analysis was based on building characteristics research conducted by Ecotope, updated modeling analysis being developed for the Regional Technical Forum (RTF) and updated modeling conducted by O'Brien360 for this project. As part of the RTF building stock calibration study, the contractor performed a series of sensitivity analyses on modeled data to identify the range of performance outcome impacted by different modeling input assumptions. In combination with Ecotope research and updated modeling, the project team has identified a number of key characteristics of building performance that will be updated for the final analysis to arrive at a more market-focused building performance baseline for the 2006 WSEC.

Internal Load Sensitivity and Impacts on Building Energy End Use

A key aspect of this analysis is to determine the degree to which different assumptions about unregulated loads impact regulated and overall building energy use, to improve the accuracy of baseline performance predictions, and so that policy assumptions about the 2006 baseline can take into consideration the impact of unregulated loads on policy and code goals. Changing assumptions about unregulated loads not only affects the anticipated total energy use of the buildings, but can have significant impact on regulated loads in the building as well.

Based on the research and data reviewed, we have identified specific building loads within key building types for analysis. Most of the analysis focuses on unregulated loads, but the impact of lighting power density and window area changes were evaluated for some building types. Unregulated loads include plug loads and other

miscellaneous electrical loads, schedule and set point adjustments, kitchen energy use, domestic hot water consumption, etc. Specific loads analyzed for each building type are identified below, and end use impacts are identified for some of these cases in the accompanying graphs.

Multifamily Buildings

The impacts of the following loads on total energy use were considered. In Figures 1 and 2 below, reductions in receptacle loads result in significantly increased heating loads and a small increase in fan energy, but a reduction in cooling loads. These graphs compare end use results from the first round of analysis with more recent updated results.

- Domestic hot water usage per person (not yet incorporated into the results shown below)
- Equipment power density
- Outdoor air per person

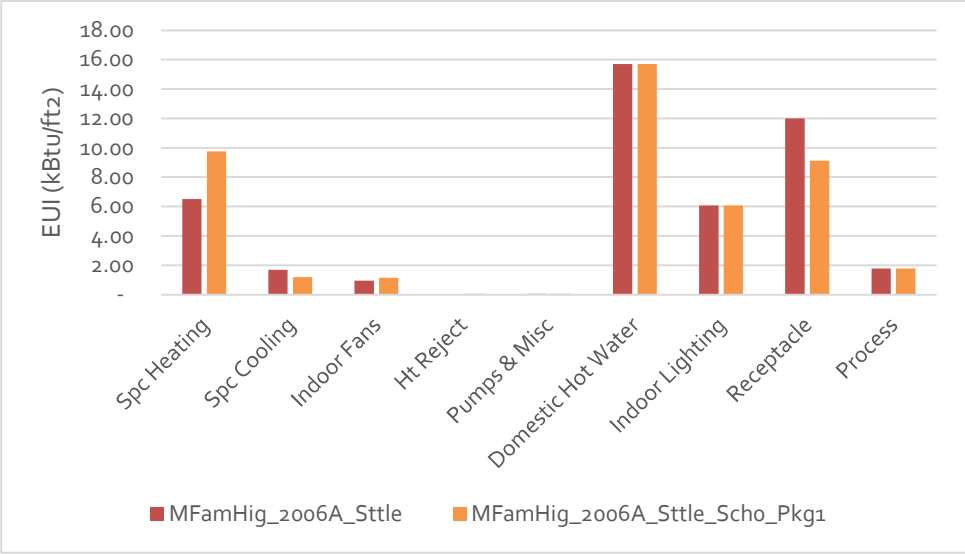

Figure 1. Updated High-Rise Multifamily results for 2006 baseline by end-use.

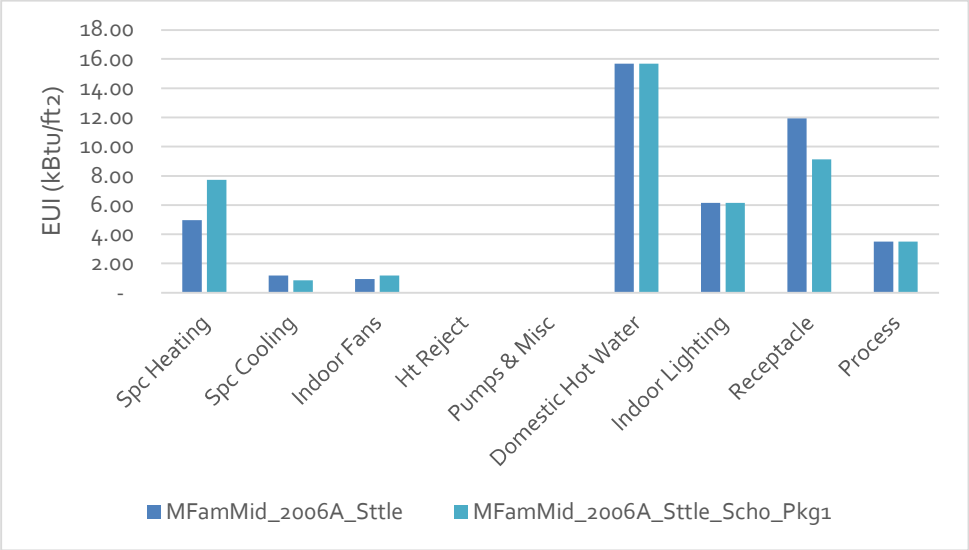

Figure 2. Updated Mid-Rise Multifamily results for 2006 baseline by end-use.

Hotel

A range of outcomes for the following loads were evaluated:

- Domestic hot water usage per person
- Lighting power density
- Equipment power density
- Kitchen gas usage (for large hotel with kitchen)

Residential Care

- Domestic hot water usage per person
- Lighting power density

Restaurant

- Kitchen gas usage
- Equipment power densities
- Domestic hot water

Retail (Strip mall and stand-alone)

- Setpoint
- Equipment power density

Supermarket

- Setpoint
- Lighting power density
- Equipment power density

Schools

In the school building types, significant reductions in receptacle loads were analyzed, reflecting results of research on school building use patterns and load adjustments adopted by the RTF to the prototypes for these building types. Figures 3 and 4 below show increases in heating load after significant reductions to receptacle loads were evaluated.

- Equipment power density

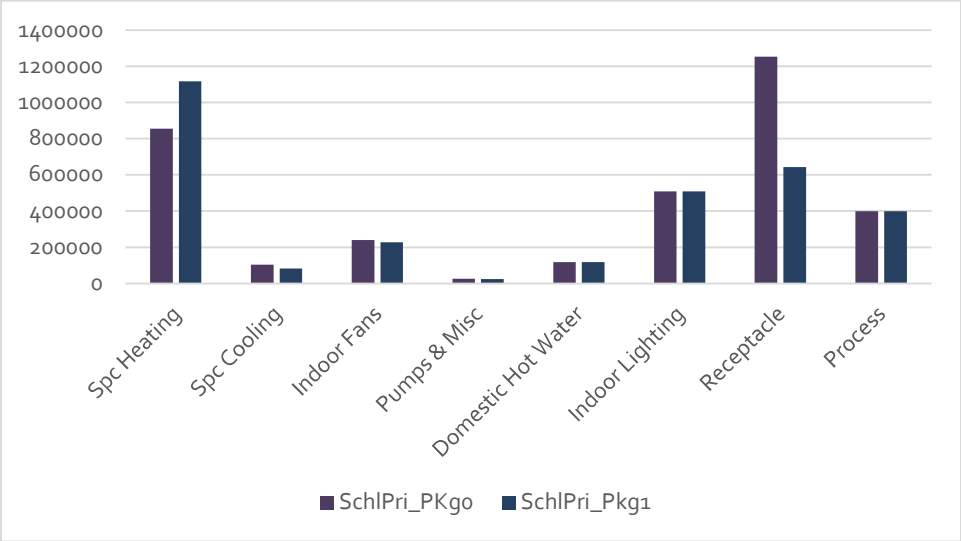

Figure 3. Updated total energy [kBtu/yr] for Primary School in 2006 baseline by end-use.

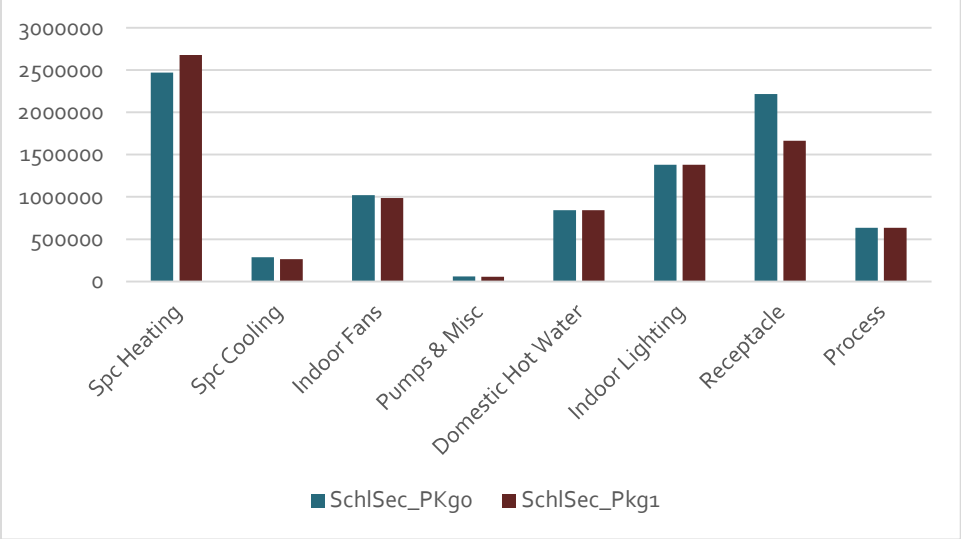

Figure 4. Updated total energy [kBtu/yr] for Secondary School in 2006 baseline by end-use.

Office

Changes to equipment power density and outdoor air flow rates led to changes in anticipated heating, cooling, and fan energy requirements, as indicated in Figure 5 below.

- Equipment power density
- Outdoor Air
- Window Wall Ratio

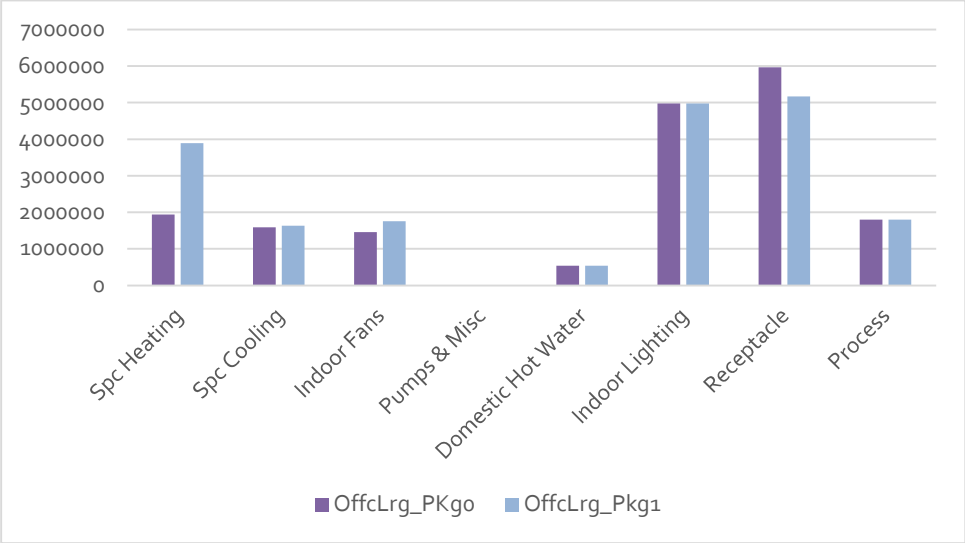

Figure 5. Updated total energy [kBtu/yr] for Large Office in 2006 baseline by end-use.

Window to wall ratio (WWR) is a building characteristic that can have significant impact on building energy use. Although window performance is regulated by the energy code, the amount of glazing allowed is more flexible, subject to some limits by the code, but not specifically proscribed. To assess the impact of different levels of WWR, the medium office prototype was modeled with a range of different WWR's, ranging from 15% to 60%. This reflects a fairly typical range of outcomes seen in the building stock. Figure 6 below shows that changes to WWR affect different building end uses by highly variable amounts, and these impacts can be significant.

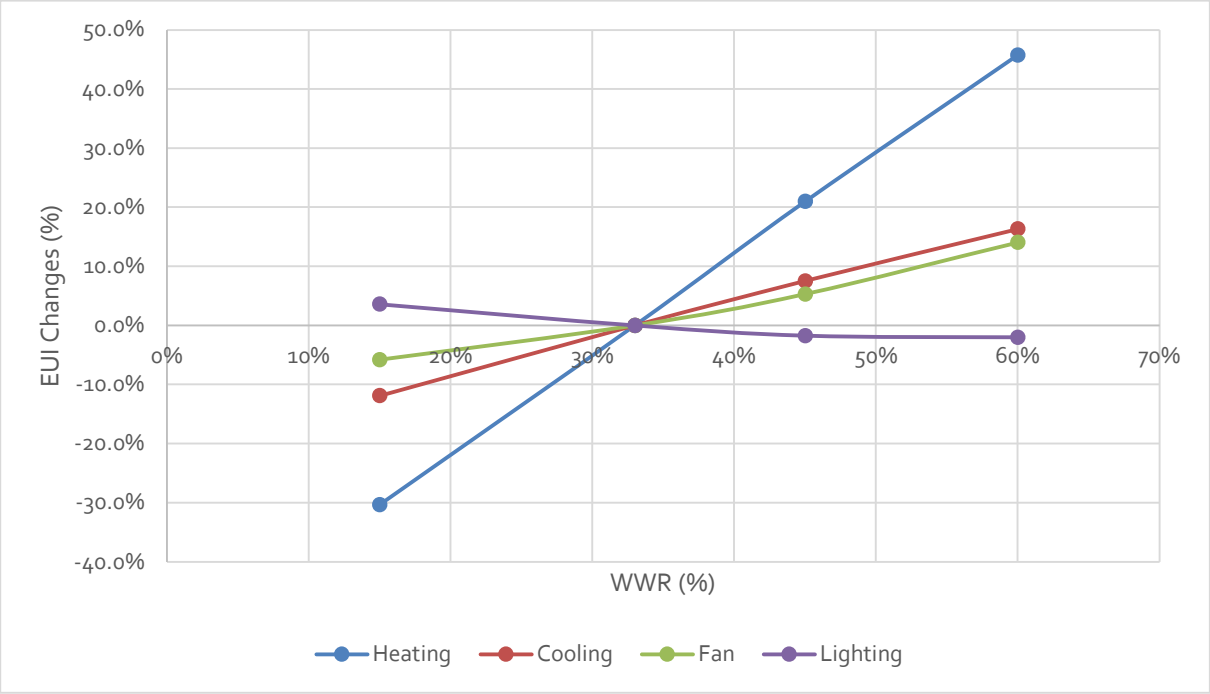

Figure 6. Impact of change in WWR on end-use energy for 2006 Medium Office prototype

Range of Performance

Taken together, the sensitivity analyses conducted on each building prototype results in a range of energy use impacts on each building type analyzed. For some building types the range of potential energy use outcome was significant, while for others the performance band was relatively narrow. The combined results for all building types analyzed is shown in Figure 7. The range shown represents an average of the range of energy impacts of different input assumptions on performance outcome for each project type, treating each load impact as an independent variable. The individual data point for each building type shows the 2006 EUI baseline for each project type calculated in the previous analysis.

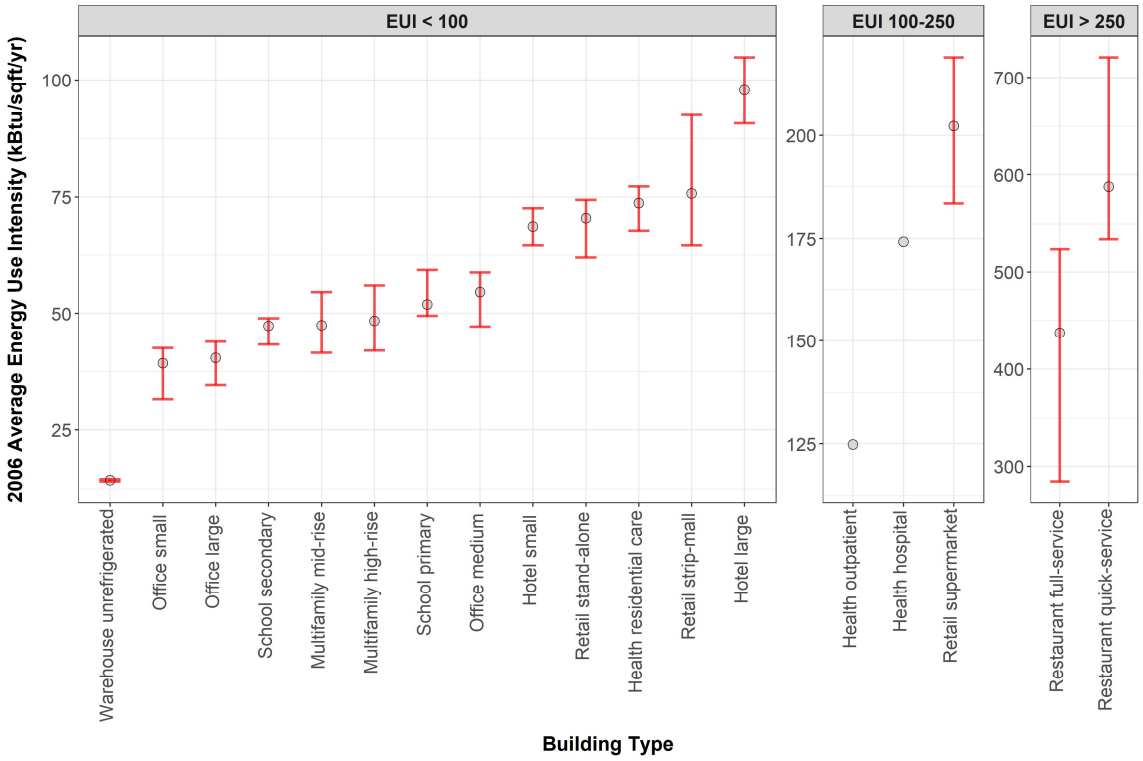

Figure 7. 2006 baseline model average EUI variation due to unregulated loads.

The results in Figure 7 indicate that more in-depth research into unregulated loads could change the mean EUI value of each building type. All building types other than Health outpatient and Health Hospital were included in the sensitivity analysis. The ranges shown here suggest that the impact of unregulated loads on individual building types represents a significant unknown in determining overall building stock progress toward state mandates for a 60% performance improvement by 2030. To reduce the uncertainty associated with unregulated loads, subsequent field analysis of building stock should focus on more specifically identifying actual energy use patterns associated with unregulated loads, rather than focusing only on the impact of energy code measures.

In the next phase of this analysis, Ecotope will use these results in combination with related ongoing analysis and published research papers to update the analysis to reflect a best engineering judgement of appropriate levels of unregulated loads, and apply these values to update the 2006 baseline analysis results. This updated analysis will identify the best estimate of 2006 baseline EUI targets for each prototype.

Residential Sector Analysis Update

For the single-family residential sector (including townhomes) specific modifications to the 2006 and 2018 code baseline analysis characteristics identified in Phase One have been identified and adopted in the analysis.

Updates in this phase include:

2006

- 2006 baseline: Increased the gas furnace efficiency from and AFUE of 0.78 (federal standards) to 0.82 (sampled average in a 2006 study of new construction)[1]

2018

- Sensitivity analysis was conducted to determine the effect of Townhomes being classified as a "Small Dwelling Unit" per Section R406.3. Townhomes represent 5% of the total weighted floor area and this adjustment assumes all townhomes now fall under the this reduced dwelling unit size, instead of "Medium" homes.
    - The RTF townhome prototype was previously 1,500sf, putting this in the "Medium Dwelling Unit" category and requiring 6.0 credits to comply with the 2018 code. If a builder were to build with a finished floor area if 1,499sf, then they would only be required to choose 3 credits. This is presented as a means to show a lower bound of energy savings introduced by the 2018 code; future building stock assessments can better inform prototypical weighting changes across this sector.
- Minor updates to match adopted WA State amendments of the 2018 IRC (ventilation in single-family)
- Central furnace fan efficiency was updated to match current federal standards[2]

The results of this analysis are shown in Figure 8. The energy use intensity of both the 2006 baseline and the 2018 code are reduced slightly from the Phase One modeling. Though the new assumptions more accurately reflect building stock characteristics, the outcome in terms of modeling represents only a minor change in overall energy use in the residential sector. Previous analysis showed a savings of 39% for the 2018 code over the baseline in the residential sector. Updated modeling now gives a savings range of 37.5% to 39% over the 2006 baseline.

[1] Table 111. Northwest Energy Efficiency Alliance. (2007). *Single-Family Residential New Construction Characteristics and Practice Study*. RLW Analytics.

[2] https://www.ecfr.gov/cgi-bin/text-idx?SID=0423028877ce42bb0c3e0e2529ac80ba&mc=true&node=se10.3.430_132&rgn=div8

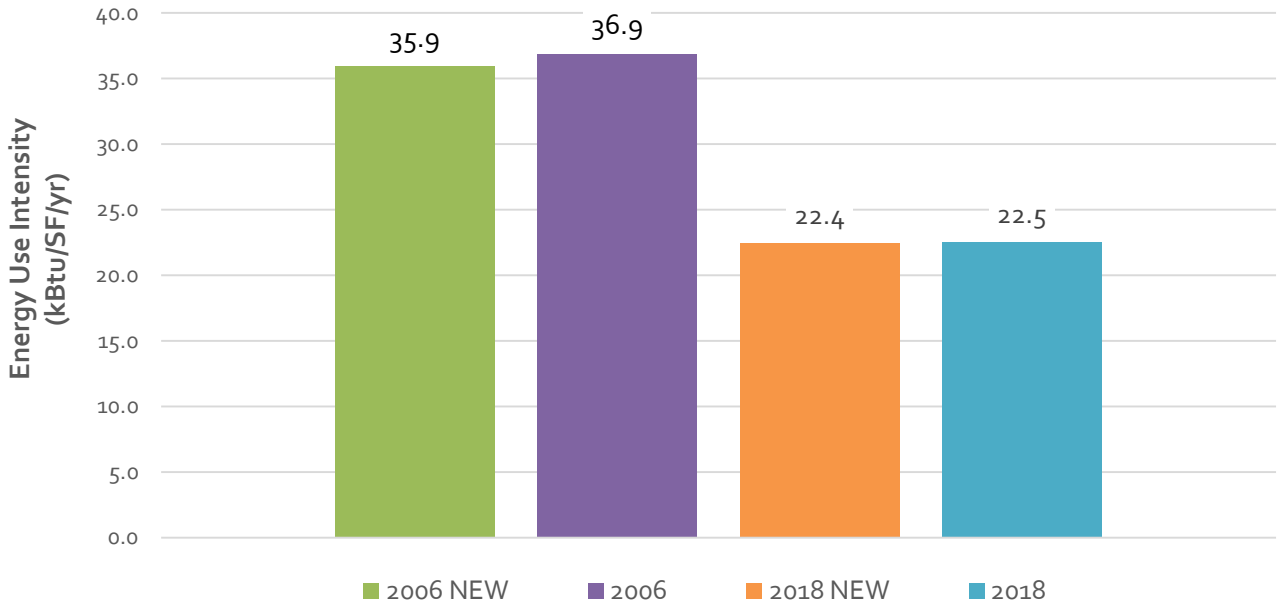

Figure 8: Residential Sector EUI by Code Year (2006 and 2018) – UPDATED