Climate Change in Canada: Impacts on Building Energy Use Intensity

Nathan Kegel

IES, Ltd.

Minneapolis, MN

ABSTRACT

Whole building energy simulation is a useful tool in assessing building energy performance and many codes require energy simulation. One of the key inputs into the building energy model is climate data. Climate data impacts virtually every dependent variable in an energy simulation including HVAC efficiency, solar heat gain, and conduction. Many energy codes require the use of certain climate files which often contain climate data that is not recent. Given the scientific consensus that rapid climate change is being seen around the globe, using old climate data may have detrimental impacts on designing or retrofitting buildings that will see dramatically different climates in the future. This research explored varying the type and date range of climate data in Vancouver, Canada to ascertain the impact of climate change on building energy use intensity (EUI). The results show significant variations in building EUI for four building types in Vancouver. Further, the results show that varying climate conditions can alter the "optimal" solution for building materials, HVAC system selection, and more.

INTRODUCTION

Climate change is well-documented in the scientific research. While most public attention focuses on average annual temperature, regional and local variation shows significantly larger surface temperature changes than the average.

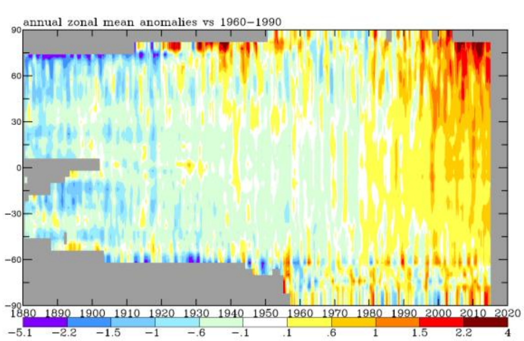

Figure 1: Annual average land surface temperature variation compared against a 1960-1990 average in °C

According to surface temperature data from the US National Aeronautics and Space Administration (NASA), the past 15 years (year 2000 to year 2015) show significant temperature changes of up to 4°C when compared to an average temperature from the period of 1960-1990. This is significant because many climate data sets including CWEC and TMY2 use climate data from 1960-1990 and these climate data sets are widely used in building energy simulation. As the graph shows, higher latitudes have the largest temperature variation. This indicates countries that are further from the Equator (like Canada) are likely to be the first to experience the most significant impacts of climate change.

Building rating systems and building energy codes in various places around the world rely on climate data for use in energy simulation. Some governments rely on the data as it integrates into the energy simulation process for validating new energy codes and deriving baseline conditions for comparison. This research studies the potential impact on total building EUI by varying climate data sets sourced from different time intervals.

Beginning in the 1980's, researchers began studying the impact climate change might have on building EUI (Loveland & Brown, 1989). The methodology used Heating Degree Day (HDD) and Cooling Degree Day (CDD) methods coupled with modified climate data to explore the potential changes in EUI caused by climate change. Using these methods, researchers estimated climate change could alter building EUI in various locations in the USA by up to 14%.

More recently, the United States Green Building Council (USGBC) commissioned a study to explore the impacts of climate change on building EUI in various regions in the USA. The subsequent report listed several recommendations for design teams including using multiple climate files in the process of designing buildings to account for an uncertain climate future (Larsen, et.al., 2011).

The climate data used in this research has been sourced from the United States Department of Energy (DOE), Weather Analytics, ASHRAE, and the Canadian Weather Energy and Engineering Data Sets (CWEEDS).

TMY3 data sets are sourced from Weather Analytics and contain weather data for the specified location from the period 1990-2005. CWEC data sets were sourced from the US DOE and contain data from the period 1960-1989. TMY7 data sets were sourced from Weather Analytics and contain data from the period 2007-2014. TMY15 data sets were sourced from Weather Analytics and contain data from the period 2000-2014. Further information about TMY data sets can be found in ASHRAE 2013 Fundamentals Chapter 14 Climatic Data and from Weather Analytics (www.weatheranalytics.com).

XMY data sets (eXtreme Meteorological Year) contain data from the period 1970-2014. XMY MAX contains the warmest temperature recorded during that period on an hourly average basis. XMY MIN contains the coldest hourly average temperature on an hourly average basis. XMY data was included to account for extreme years. Extreme years are considered among climate scientists to be more likely in the future. With nearly every year being hotter than the previous year, the data trend bears evidence that extreme weather events (including temperatures) are in fact occurring today and increasing in frequency when compared to previous time periods.

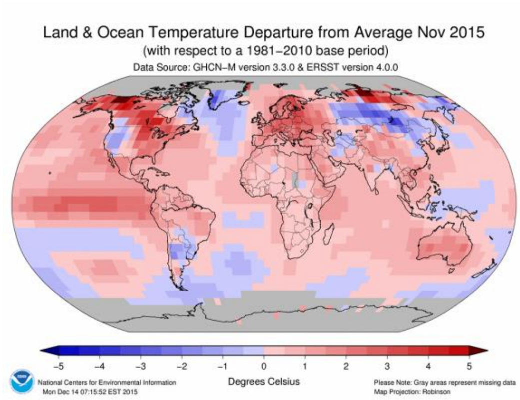

Figure 2: Land & Ocean Temperature Departure November 2015 from Average with Respect to a 1981-2010 base period

The National Oceanic and Atmospheric Administration (NOAA) data also shows significant temperature departures from average. The general trend of being further from the Equator showing larger temperature increases is also shown in NOAA surface temperature data. Surface temperatures in Canada and the northern USA show up to a 5°C increase over previous average surface temperatures.

METHODOLOGY

This research uses the US DOE medium office reference building located in Vancouver, BC. ASHRAE 90.1-2007 baseline constructions, HVAC systems, internal gains, and building operational schedules were used.

DOE Medium Office Reference Building	
Storeys	3
Floor Area	4982 m^2
Occupied Hours	8 AM to 6 PM; M-F
Heating Setpoint	21°C
Cooling Setpoint	24°C
HVAC System	PSZ, Constant Volume
Cooling Source	Electricity
Heating Source	Natural Gas

Table 1: Basic Building Inputs for DOE Medium Office Reference Building

DOE Hospital Reference Building	
Storeys	5
Floor Area	22,422 m2
Occupied Hours	24/7
Heating Setpoint	21°C
Cooling Setpoint	24°C
HVAC System	VAV, DOAS, PSZ
Cooling Source	Electricity
Heating Source	Natural Gas

Table 2: Basic Building Inputs for DOE Hospital

DOE Small Hotel Reference Building	
Storeys	4
Floor Area	4013 m2
Occupied Hours	6PM to 6 AM M-F
Heating Setpoint	21°C
Cooling Setpoint	24°C
HVAC System	PSZ, CAV
Cooling Source	Electricity
Heating Source	Natural Gas

Table 3: Basic Building Inputs for DOE Small Hotel

DOE Secondary School	
Storeys	2
Floor Area	19,592 m2
Occupied Hours	7AM to 5 PM, M-F
Heating Setpoint	21°C
Cooling Setpoint	24°C
HVAC System	VAV
Cooling Source	Electricity
Heating Source	Natural Gas

Table 4: Basic Building Inputs for DOE Secondary School

All building inputs are further detailed at http://energy.gov/eere/buildings/commercial-reference-buildings

One way to assess variation in climate data is to use a BIN analysis to assess the variation and duration of conditions in a climate data set. Each climate file used in this analysis was assessed using a BIN analysis to show the variation in dry bulb temperatures among the climate data sets used in this research. Figures 3-8 below show a BIN analysis for each climate file used in this research.

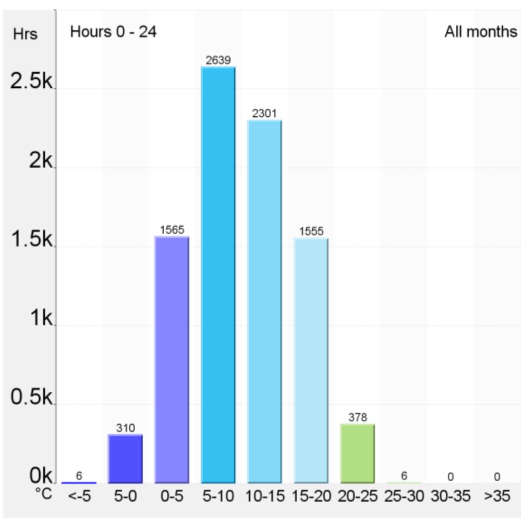

Figure 3: BIN analysis of hourly dry-bulb temperatures, Vancouver CWEC

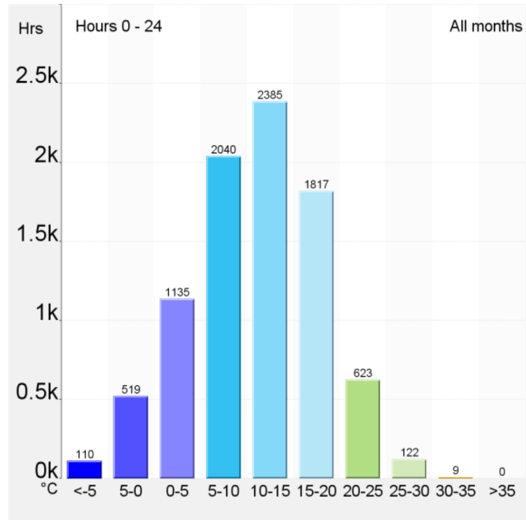

Figure 4: BIN analysis of hourly dry-bulb temperatures, Vancouver XMY MAX

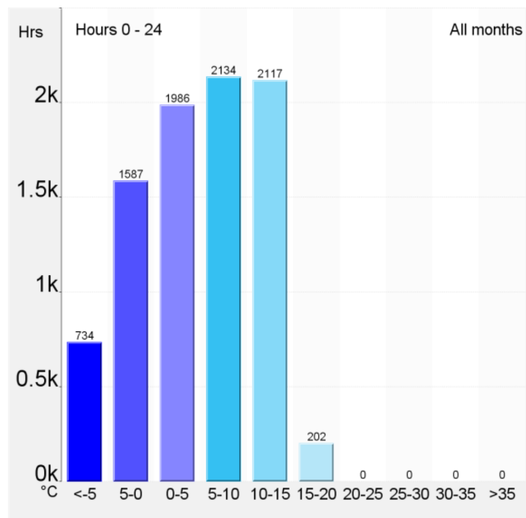

Figure 5: BIN analysis of hourly dry-bulb temperatures, Vancouver XMY MIN

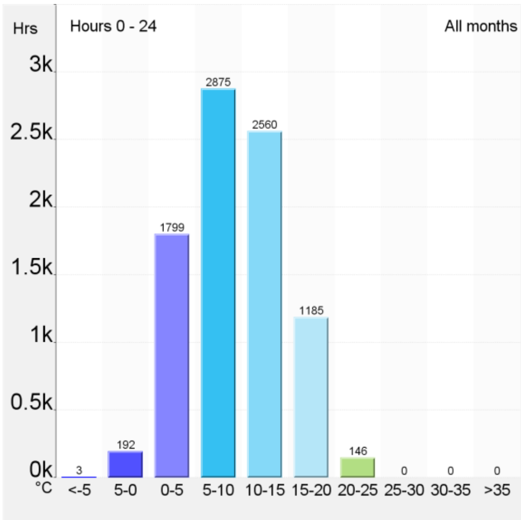

Figure 6: BIN analysis of hourly dry-bulb temperatures, Vancouver TMY7

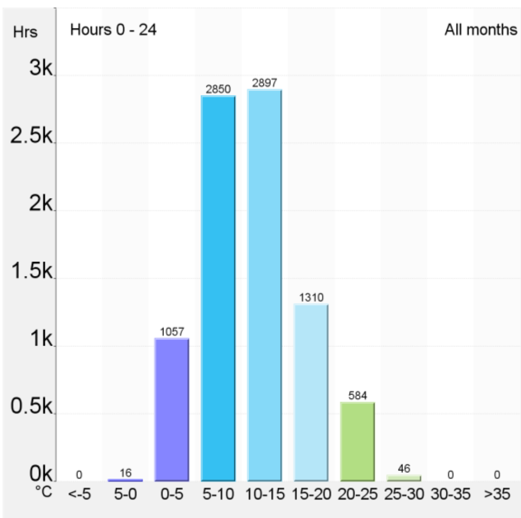

Figure 7: BIN analysis of hourly dry-bulb temperatures, Vancouver TMY3

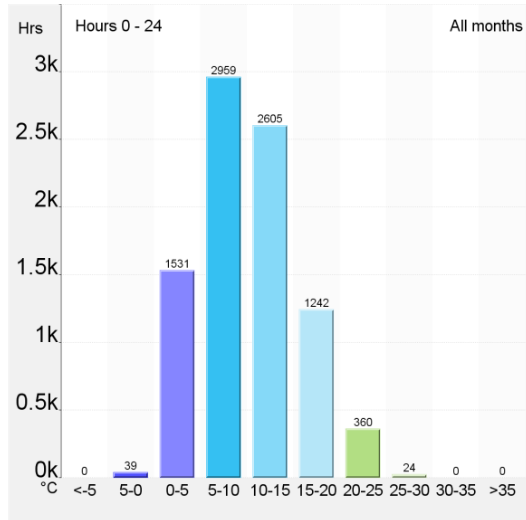

Figure 8: BIN analysis of hourly dry-bulb temperatures, Vancouver TMY15

Climate File	Climate Zone
XMY MAX	4C
XMY MIN	7
CWEC	5C
TMY3	4C
TMY7	5C
TMY15	5C

Table 5: Derived ASHRAE climate zone for each climate file using ASHRAE 90.1 methodology

As energy codes and Standard 90.1 uses climate zone to define the baseline building parameters for comparison, altering climate files within the same location can lead to differing climate zones and baseline building types.

Several additional building types were evaluated but not included in this paper.

ANALYSIS

The simulations used IES Virtual Environment (IESVE) software to study peak HVAC loads, building EUI, and energy end uses. Simulations were run in a parametric processor to ensure inputs were the same between simulations (except for changing which climate data set was used).

IESVE contains powerful analysis tools to interrogate the results of the simulations. The analysis focused on interrogating deltas in peak HVAC load, total building EUI, and building energy end uses.

Comparison of the results used the CWEC climate data set as the “baseline”. This was chosen as

CWEC are most commonly used in building simulation for LEED and code compliance in Canada. CWEC also contain older data sets for comparing against NASA and NOAA climate data for purposes of correlation.

Each of the simulation results was analysed in the VistaPro application of IESVE to compare building EUI, peak load, and energy end usage among the building types and with varying climate data sets.

RESULTS

The results of the simulations show significant variations in building EUI, peak HVAC load, peak electricity demand, peak natural gas demand, and significant variation in energy end uses for each of the building types. The variation is more significant when XMY data is used than when TMY data is used. This is expected as TMY data tends to minimize the impact of extreme elements while XMY data is setup to account more for extreme conditions than "typical" conditions.

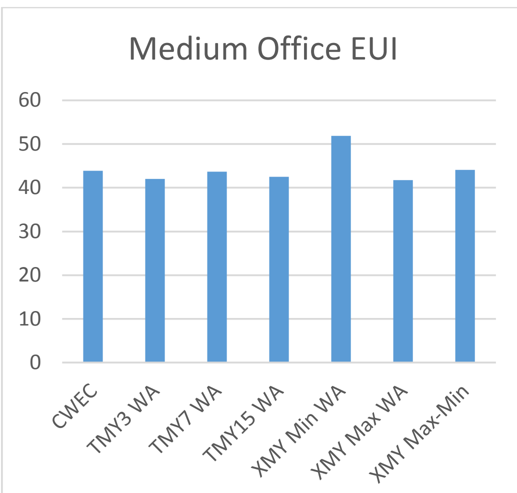

Figure 9: Medium Office EUI in Vancouver using various climate data files. Y-axis units are kbtu/square foot/year.

The EUI for the medium office varies by 23% when varying the climate data in energy simulation. When XMY data is excluded, the variance is 4%.

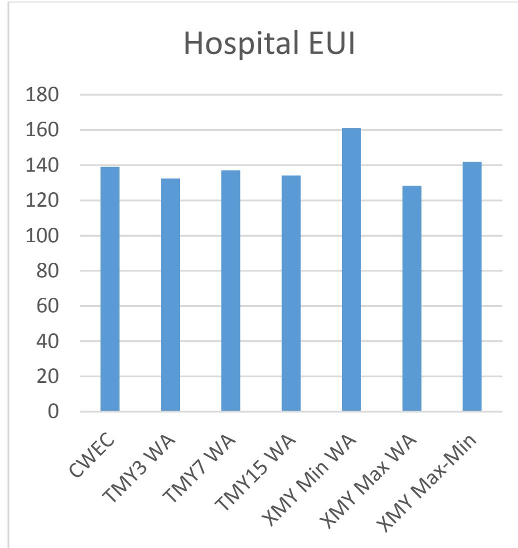

Figure 10: Hospital EUI in Vancouver using various climate data files. Y-axis units are kbtu/square foot/year.

The hospital EUI varies by 24% when varying the climate data in the energy simulation. When XMY data is excluded, the variance is 5%.

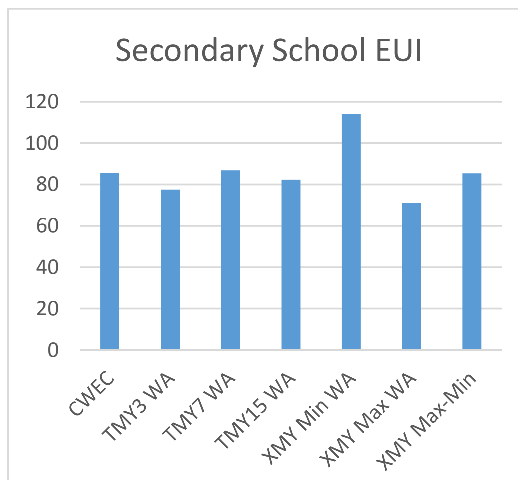

Figure 11: EUI variance for Secondary School. Y-axis units are kbtu/square foot/year.

The secondary school EUI varies by 50% when varying the climate data in energy simulation. When XMY data is excluded, the variance is 11%.

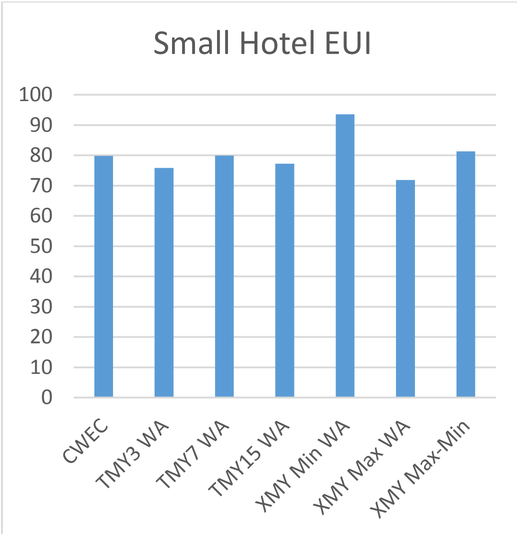

Figure 12: EUI for Small Hotel in Vancouver using various climate data files. Y-axis units are kbtu/square foot/year.

The small hotel EUI varies by 27% when using various climate data in the energy simulation. When XMY data is excluded the variance is 5%.

The energy end-uses are broken out in the Appendix in detail. The general trend in the climate data is a warming of the climate. This indicates that buildings in Vancouver will require less natural gas for heating and more electricity for cooling and other end uses. These variances show more significant impacts on the design of buildings ranging from heating and cooling equipment size to anticipated source energy requirements.

In Vancouver, the variance in EUI is likely less noticeable due to the impacts of the marine climate and the adjacent Pacific Ocean. However, the climate data used assumes that the ocean currents would remain the same in this analysis. Various climate models and ocean current models suggest significant variation in temperature of the ocean currents may occur if climate change remains unchecked (RCP Database, 2016). Thus, future work where future climate files account for potential variation in ocean currents may cause a more significant variation the model.

It's important to note that all the buildings studied do not exceed 40% window-to-wall ratio. As glazing is generally a good conductor of heat and allows for solar radiation to enter the building, limiting the amount of glazing likely mutes the impact of climate file data variation. Buildings that have significantly more glazing than the theoretical buildings used in this analysis are therefore more likely to see larger variations in EUI, peak HVAC load, electrical energy consumption and natural gas consumption.

All building types show a significant variation in EUI when different climate data is used in the simulations. However, the drivers for variation in each building type are different. The small hotel building energy consumption is driven most by conduction through the envelope. The secondary school and the hospital energy consumption are driven by ventilation requirements and air change requirements. The office energy consumption is driven largely by internal gains including lights and plug loads.

CONCLUSIONS

Accuracy in building energy simulation is significantly dependent on available climate data. Rapid climate change is causing past climate data to be less representative of actual current and future climate conditions. Decisions in the building design and/or retrofit process should not be dependent on using only a single set of climate data especially if the climate data contains data that was recorded more than 10 years ago.

Design teams need to account for climate change in the design and retrofit of buildings. Government agencies, code authorities, and building rating systems also need to account for climate change in building energy performance. Therefore, additional data about the weather and incorporation of future climate models into local and regional climate change forecasting is an essential step in ensuring climate change is properly accounted for when considering building energy design.

Given the availability of climate data, future climate models, and statistical methods for incorporating uncertainty into models, new approaches for developing future climate data sets are required to adequately account for rapid climate change in the design and retrofit of buildings.

In lieu of this type of statistical models and generation of future climate data, design teams should strongly consider using more recent climate data in TMY format at a minimum. A better approach would be to additionally include extreme weather data to understand the variance associated with an extreme climate. Design teams could then use this assessment of several climate models coupled with their own assessment of climate change models to determine the best design decisions for the building for the future climate.

Further research using other locations in Canada would likely show larger variations in EUI. The extent of the variation would likely have a larger impact on optimal selections of glazing, HVAC, and building form (among other considerations in the design process).

ACKNOWLEDGEMENTS

This research would not be possible without the assistance of Weather Analytics who supplied various climate files.

REFERENCES

ASHRAE Handbook of Fundamentals 2013. American Society of Heating, Refrigeration, and Air-Conditioning Engineers

ASHRAE Standard 90.1-2007. *Energy standard for buildings except low-rise residential*. American Society of Heating, Refrigeration and Air-Conditioning Engineers

ASHRAE Standard 90.1-2010. *Energy standard for buildings except low-rise residential*. American Society of Heating, Refrigeration, and Air-Conditioning Engineers

IES Virtual Environment software version 2015 Feature Pack 1. *Integrated Environmental Solutions, Ltd*. Available from www.iesve.com

Loveland, J.E. & Brown, G.Z. (1989) *Impacts of Climate Change on the Energy Performance of Buildings in the United States*. Retrieved August 15, 2015 from https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/10462/impacts_of_climate.pdf?sequence=1

Crawley, D. (1998) *Which weather data should you use for energy simulation of commercial buildings?* Retrieved August 18, 2015 from http://gundog.lbl.gov/dirpubs/1801_weath.pdf

Crawley, D. (2008) *Building performance simulation: a tool for policymaking*. Retrieved August 15, 2016 from www.esru.strath.ac.uk/Documents/PhD/crawley_thesis.pdf

Sustainable United Nations (2009), *Buildings and Climate Change: Summary for Decision Makers*. Retrieved September 30, 2015 from http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf

Larsen, et. al. (2011) *Green Building and Climate Resilience: Understanding impacts and preparing for changing conditions*. Retrieved, August 15, 2015 from http://www.usgbc.org/resources/green-building-and-climate-resilience-understanding-impacts-and-preparing-changing-conditi

Bhandari, Srhestha, New (2012) *Evaluation of weather data sets for building simulation*. Energy and Buildings, Volume 49, pgs. 109-118

National Aeronautical and Space Administration (2016). Record of recorded surface temperatures. http://data.giss.nasa.gov/gistemp/time_series.html

RCP database, retrieved January 14, 2016 from http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome

Appendix

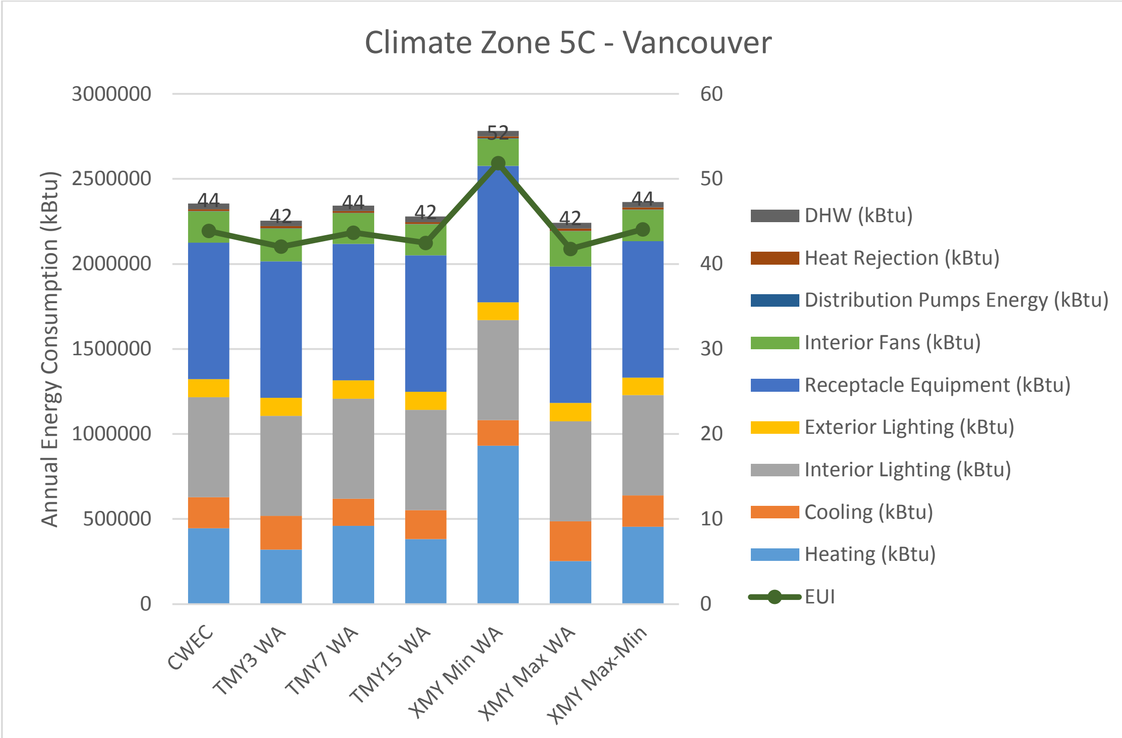

Figure 13: Medium office energy end-usage with various climate data (EUI units: kbtu/square foot/year)

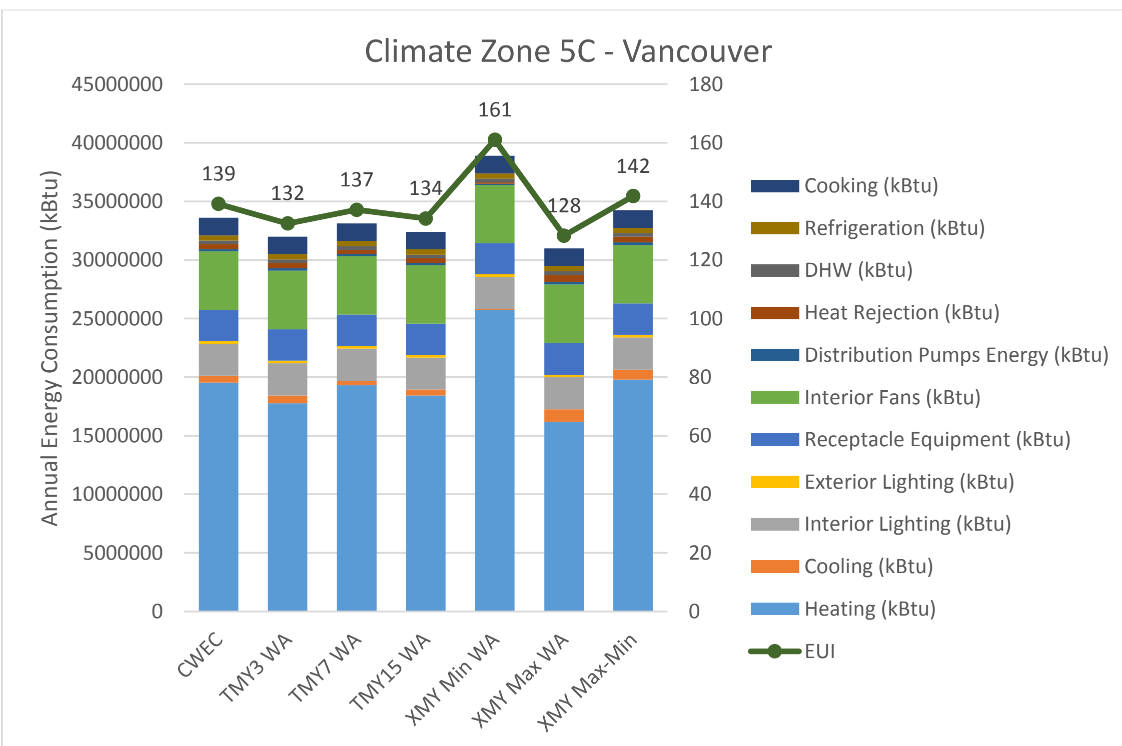

Figure 14: Hospital energy end-usage with various climate data (EUI units: kbtu/square foot/year)

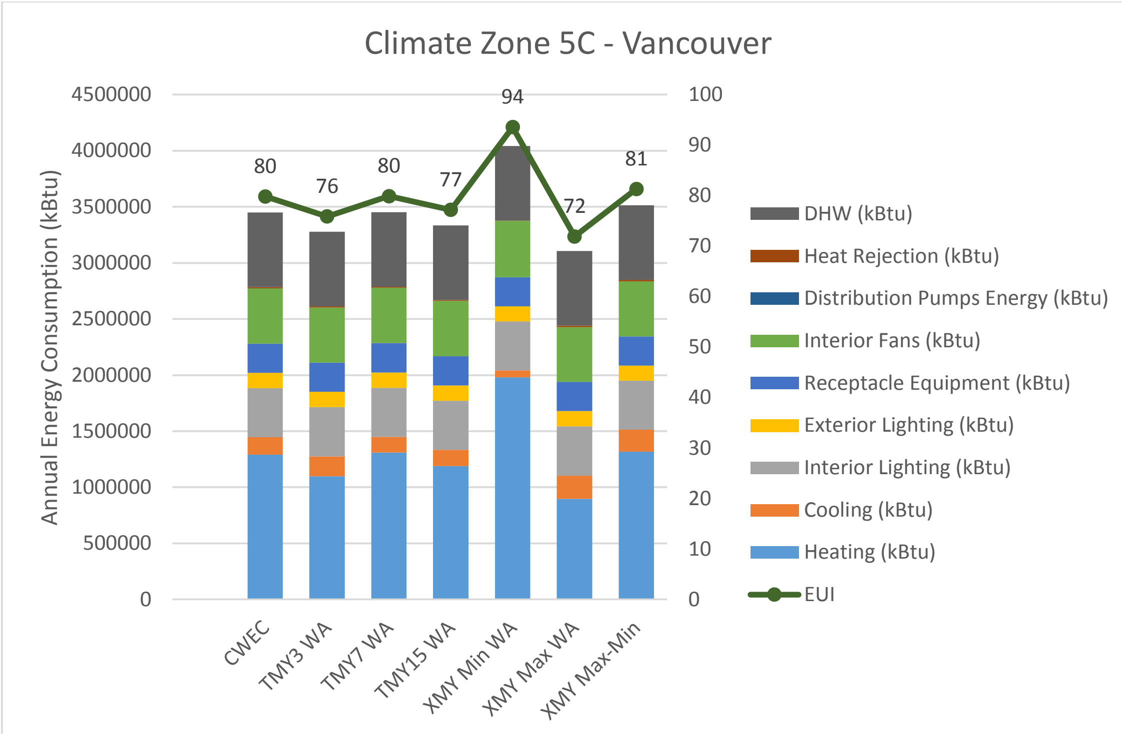

Figure 15: Small hotel energy end-usage with various climate data (EUI units: kbtu/square foot/year)

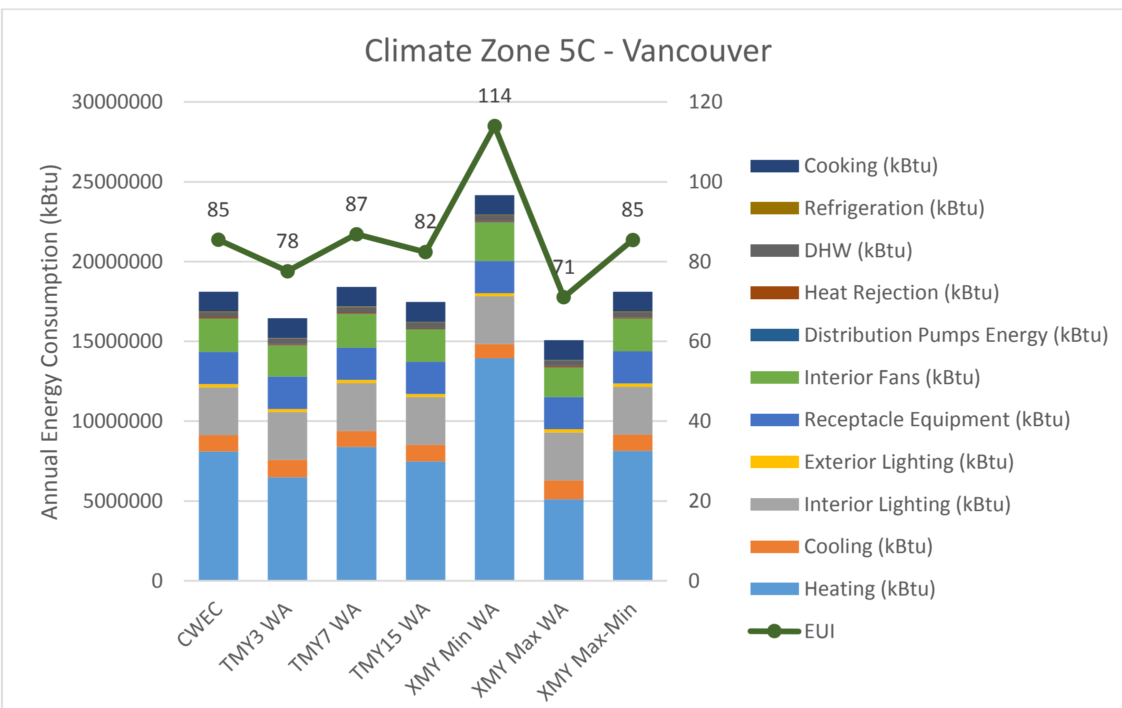

Figure 16: Secondary school energy end-usage with various climate data (EUI units: kbtu/square foot/year)