IMPACT OF WEATHER DATASET SELECTION AND SOLAR IRRADIANCE REPRESENTATION ON BUILDING ENERGY SIMULATION IN CANADIAN CLIMATES

Summary

Weather data represent a primary boundary condition in building energy simulation and strongly influence predicted heating and cooling demand as well as solar energy system performance. This study evaluates the influence of weather dataset selection, solar irradiance assumptions, and weather file generation methods on simulated building energy performance across several Canadian climates. Parametric building energy simulations were conducted using the Grasshopper–Honeybee interface coupled with EnergyPlus for three representative building archetypes: detached houses, multi-unit residential buildings (MURBs), and office buildings. Three analyses were performed: comparison of historical weather datasets (CWEEDS, PSM4, ERA5), sensitivity of solar irradiance variations (±10% DNI and GHI), and comparison of typical and extreme meteorological year generation methods. The preliminary results indicate that heating loads remain relatively consistent across datasets, while cooling loads and solar gains vary substantially due to differences in solar radiation representation.

Keywords: building energy simulation, weather datasets, solar radiation, TMY, XMY, Canadian climate

Field of application for the findings: Solar buildings, building energy modeling, climate-responsive building design

Addressed audience: Researchers, building energy modelers, solar energy system designers, policy and standards developers

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1. Introduction

Weather data constitute one of the most important inputs in building energy modeling (BEM). Outdoor temperature, solar radiation, humidity, and wind conditions directly influence building heating and cooling demand as well as the performance of renewable energy technologies such as photovoltaic systems. In Canada, building simulations commonly rely on Typical Meteorological Year (TMY) datasets derived from long-term historical observations. The Canadian Weather Year for Energy Calculation (CWEC) dataset is widely used for building performance simulations and regulatory assessments. These datasets are constructed by selecting statistically representative months from multi-year weather records in order to generate a synthetic year that approximates long-term climate conditions.

Although TMY datasets provide a practical representation of average climatic conditions, they also introduce limitations. The statistical construction process smooths climatic variability and excludes many extreme weather events. Consequently, building simulations based solely on typical weather years may underestimate peak energy demand or fail to capture the effects of extreme climatic conditions.

These limitations are particularly relevant in the context of increasing solar energy integration, electrification of heating systems, and climate-resilient building design. Variations in solar radiation and extreme temperature conditions can significantly influence both building energy demand and solar energy system performance.

The objective of this study is therefore to investigate how different weather datasets, solar irradiance assumptions, and weather file generation methods influence building energy simulation outcomes across several Canadian climates.

2. Methodology

Building energy simulations were performed using EnergyPlus for three representative building archetypes: a detached house; a multi-unit residential building (MURB) and an office building (Fig.1). The preliminary results presented in this extended abstract focus on the detached house archetype modeled using envelope characteristics corresponding to ASHRAE 2004 construction standards. Simulations were conducted for four Canadian cities representing different climate zones: Halifax (Zone 6A), Toronto (Zone 5A), Regina (Zone 7), and Vancouver (Zone 4C).

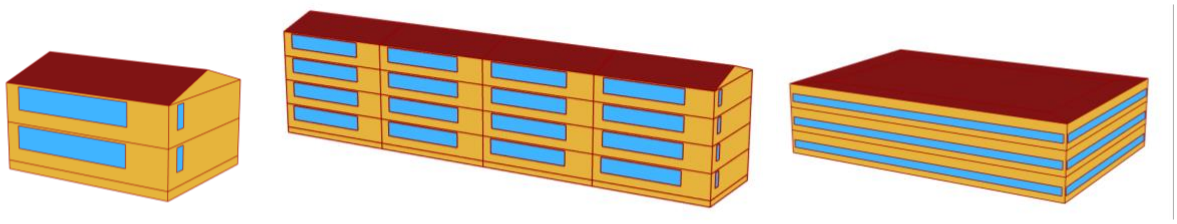

Figure 1. Modelled building archetypes: Detached house.;) Multi-unit residential building and Medium office building

Envelope properties, internal gains, and operational parameters were kept constant across locations in order to isolate the impact of weather data on building energy performance. Three analyses were conducted. First, historical weather datasets were compared using weather files derived from CWEEDS, PSM4, and ERA5. Annual heating and cooling loads, peak demands, and solar radiation were evaluated using multi-year averages from 2005–2022. Second, a solar irradiance sensitivity analysis was performed by modifying direct normal irradiance (DNI) and global horizontal irradiance (GHI) values in CWEC TMY weather files by ±10%. The resulting impacts on heating loads, cooling loads, and solar gains were evaluated. Third, different weather file generation approaches were compared. These included several typical meteorological year methods (CWEC, ISO 15927, NO, and TMY3) and extreme weather datasets such as seasonal Extreme Meteorological Year (XMY) and TMY+XMY approaches.

3. Results and Discussion

3.1 Historical Weather Dataset Comparison

The comparison of historical weather datasets indicates that heating demand remains relatively stable across the evaluated datasets. In most cases, annual heating loads differ by less than approximately 5% from the CWEEDS baseline. Some larger variations occur, such as an approximately 11% reduction in heating demand predicted by the PSM4 dataset for Regina. Cooling loads, however, exhibit substantially larger variability between datasets. Differences between PSM4 and CWEEDS reach approximately 30–43% in some locations, while ERA5 cooling loads are up to 65% lower than CWEEDS in Vancouver (Fig. 2). These differences correspond closely to variations in solar radiation values between datasets. ERA5 weather files generally contain significantly lower solar irradiance values, resulting in reduced solar gains and lower cooling demand predictions. Conversely, PSM4 weather datasets tend to produce higher solar radiation values, leading to higher solar gains and increased cooling loads. These results demonstrate that cooling demand predictions are strongly influenced by the representation of solar radiation in the weather datasets.

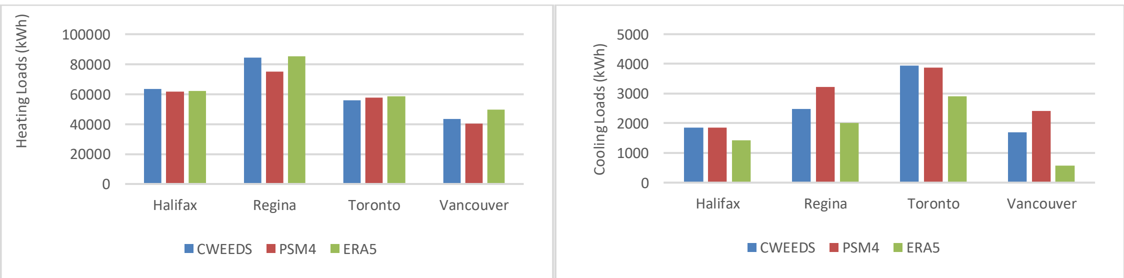

Figure 2. Detached house annual heating loads by location for each weather dataset; Detached house annual cooling loads by location for each weather dataset.

3.2 Sensitivity to Solar Irradiance

The solar irradiance sensitivity analysis shows that heating demand is only marginally affected by moderate variations in solar radiation. A ±10% change in direct normal irradiance results in variations of only approximately 1–2% in annual heating loads. Cooling loads exhibit greater sensitivity to solar radiation variations, with deviations reaching approximately 7% depending on location (Fig. 3). The analysis also indicates that within the EnergyPlus anisotropic sky model, direct normal irradiance plays a dominant role in determining incident solar radiation and solar gains. Changes in global horizontal irradiance alone produce negligible changes in simulation results, indicating that solar distribution calculations primarily depend on direct solar radiation.

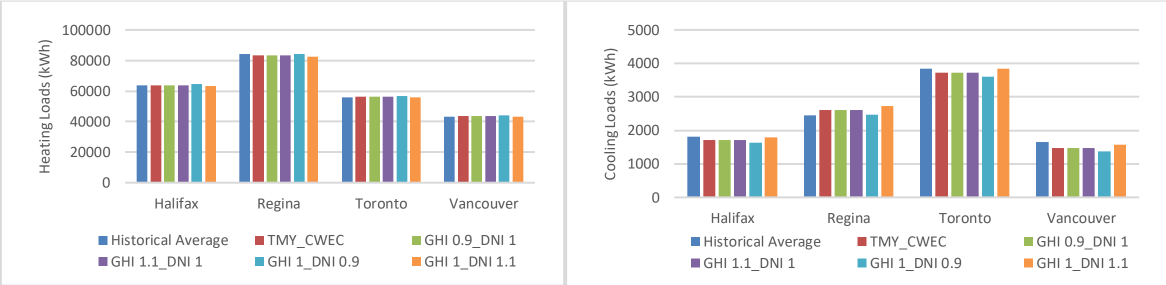

Figure 3. Effects of variation of global horizontal and direct normal irradiance on annual heating loads and) annual cooling loads for the detached house.

3.3 Weather File Generation Methods

The comparison of different weather file generation approaches shows that typical meteorological year methods produce relatively consistent annual heating loads across all cities, generally remaining within approximately 2% of historical averages. Cooling loads also remain relatively similar between TMY approaches, typically varying within approximately 5%. Differences between TMY methods are mainly associated with variations in solar radiation representation. In contrast, extreme meteorological year datasets produce significantly larger deviations. Seasonal XMY weather files increase cooling loads by approximately 50–85% relative to historical averages and increase heating loads by up to 20% in colder climates (Fig. 4). Peak heating and cooling demand predictions also differ significantly depending on the weather file generation method, highlighting the importance of weather dataset selection when evaluating building system sizing and resilience.

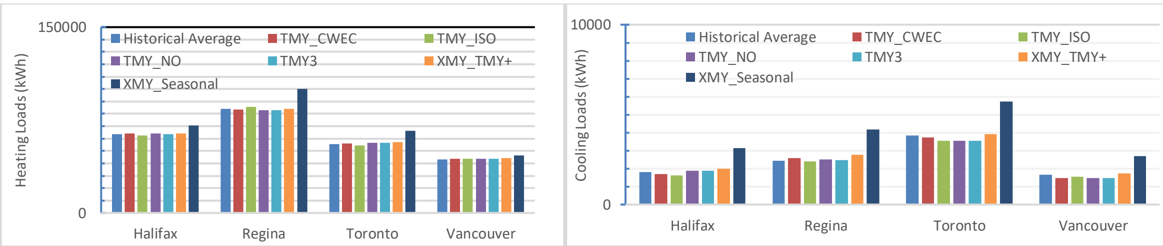

Figure 4. Differences in weather file generation methods: a) annual heating loads and b) annual cooling loads for the detached house

4. Conclusions

This study evaluates the influence of weather dataset selection, solar irradiance assumptions, and weather file generation methods on building energy simulation outcomes across several Canadian climates. Preliminary results for the detached house archetype show that heating demand predictions remain relatively consistent across weather datasets, while cooling loads and solar gains are highly sensitive to variations in solar radiation representation. Historical weather datasets produce similar heating loads but may generate significantly different cooling demand predictions due to differences in solar irradiance data. Sensitivity analysis confirms that heating demand is primarily driven by outdoor temperature, while cooling demand is more strongly influenced by solar radiation. Comparisons of weather file generation methods further demonstrate that extreme weather datasets significantly increase predicted cooling loads and peak demands, suggesting their importance for resilience-oriented building performance analysis.

The results presented here represent preliminary findings for the detached house archetype. Simulations for multi-unit residential buildings and office buildings are currently under processing and will provide further insight into how weather dataset selection interacts with building typology and operational characteristics.