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Analyzing the Impact of Future Weather Data on Energy Consumption in Weatherization Assistant

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Buildings and Transportation Science Division

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ABBREVIATIONS AND ACRONYMS

ACH	air changes per hour
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BsmC	conditioned basement
BsmU	unconditioned basement
CDD	cooling degree day
Crsp	crawlspace
DOE	Department of Energy
EF	electric furnace
fTMY	future typical meteorological year
GCM	General Circulation Model
GF	gas furnace
HDD	Heating degree day
HP	heat pump
IECC	International Energy Conservation Code
IPCC	Intergovernmental Panel on Climate Change
NEAT	National Energy Audit Tool
OF	oil furnace
ORNL	Oak Ridge National Laboratory
RCP	representative concentration pathway
SHGC	solar heat gain coefficient
SIR	savings-to-investment ratio
SRES	Special Report on Emissions Scenario
SSP	socio-economic pathway
WAP	Weatherization Assistance Program
WFR	window-to-floor ratio
WS	wind speed

EXECUTIVE SUMMARY

This study supports the mission of the U.S. Department of Energy's Weatherization Assistance Program (WAP), which aims to increase the energy efficiency of dwellings and reduce their total residential expenditures. Specifically, we examine how projected future climate conditions may affect residential building energy performance by integrating future weather data into the National Energy Audit Tool (NEAT). Since WAP evaluates the cost-effectiveness of retrofit measures over lifespans of up to 30 years, accounting for evolving climate conditions is increasingly important. To reflect future household energy demands, this study replaces historically based Typical Meteorological Year (TMY3) weather inputs with Future Typical Meteorological Year (fTMY) datasets derived from global climate model (GCM) projections.

A simulation-based framework was established to enable NEAT analysis under future weather conditions. This workflow involves converting EPW-format weather files into JSON inputs compatible with NEAT and generating degree-hour metrics needed for load calculations. The fTMY dataset used in this study was developed by Oak Ridge National Laboratory through downscaling of six GCMs under different emission scenarios and covers the period from 2020 to 2100. In contrast, the TMY3 dataset is based on historical weather data from 1961 to 1990.

Simulations were conducted for benchmark single-family prototype buildings across ASHRAE climate zones 1–7, which cover all regions of the U.S. except the subarctic Zone 8 in northern Alaska, evaluating both heating and cooling loads under TMY3 and fTMY conditions. Four foundation types were tested, while heating systems were standardized, as NEAT does not differentiate thermal energy load by HVAC system type in its load calculations. Results show that fTMY weather input consistently yield lower heating loads and higher cooling loads across most locations, aligning with expected climate warming trends. Notably, colder regions such as zones 6A, 6B, and 7 experience marked reductions in heating load, while warmer and transitional zones, such as 2A (Lufkin, TX) and 3C (San Francisco, CA), have substantial increases in cooling loads.

Although this study does not directly assess the performance of retrofit measures under future climate conditions, it provides a critical foundation for doing so. By quantifying shifts in baseline (i.e., pre-retrofit case) energy loads between historical and future weather files, the study highlights the importance of integrating climate-responsive data into audit tools. These findings will inform future efforts to evaluate the long-term effectiveness and cost-effectiveness of weatherization measures under changing climate conditions.

1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

1.1.1 Study Motivations

The Weatherization Assistance Program (WAP), administered by the U.S. Department of Energy, aims to improve energy efficiency, reduce total residential expenditures, and enhance the health and safety of dwellings owned or occupied by low-income families. As the impacts of climate change intensify, WAP may need to adjust analysis methods to ensure that energy-efficiency measures remain cost-effective under future climate conditions.

This study supports WAP's long-term mission by examining how projected climate change may influence baseline residential energy loads. Specifically, we investigate the implications of using future weather files, known as future typical meteorological years (fTMY), for evaluating building energy performance, in comparison to the historically based TMY3 datasets currently used in WAP audit tools. While this phase of the study does not directly evaluate the performance of retrofit measures under future climate conditions, it establishes the groundwork for incorporating future climate considerations into WAP-related modeling and decision-making processes.

The TMY3 datasets, which serve as standard weather inputs in audit tools, such as National Energy Audit Tool (NEAT), are derived from historical weather records spanning 1976 to 2005. Each TMY3 file represents a typical meteorological year constructed from this 30-year period using a statistical selection process. Although widely used, TMY3 may no longer reflect present-day or future climate trends. In contrast, fTMY files incorporate projections from global climate models (GCMs) based on representative concentration pathways (RCPs) and socio-economic pathways (SSPs), offering a forward-looking representation of climate conditions expected 20 to 30 years in the future.

This report presents a comparative analysis of TMY3 and fTMY inputs for representative benchmark buildings across various U.S. climate zones. By quantifying differences in annual heating and cooling loads, we aim to determine whether the use of fTMY results in significantly different energy baselines. This foundational analysis is critical for future work that seeks to assess how projected climate changes could influence the long-term effectiveness of weatherization strategies.

In summary, while this study does not directly evaluate retrofit savings under future weather conditions, it lays the groundwork for that analysis. Understanding how future climate affects baseline energy demand is a necessary precursor to evaluating how retrofits may perform under changing climate, which is an insight that may become increasingly important for WAP as it aims to deliver cost-effective energy savings over multi-decade timeframes.

1.1.2 Introduction of WAP tools

The Weatherization Assistant is a family of advanced audit tools designed specifically to help states and local weatherization agencies implement the US Department of Energy (DOE) Weatherization Assistance Program. The Weatherization Assistant is developed and maintained by DOE's Oak Ridge National Laboratory (ORNL) [Malhotra et al., 2024]. It applies engineering and economic calculations to assist states and agencies in selecting energy-efficient retrofit measures that meet programmatic criteria for cost effectiveness. The Weatherization Assistant can be used to select and rank measures for individual houses, or to establish a priority list of weatherization measures for similar housing types.

One important member among the audit tools is National Energy Audit Tool (NEAT), which is a DOE-approved energy audit tool designed to help auditors identify cost-effective energy-efficiency retrofit measures for site-built, single-family homes [Malhotra et al., 2024]. NEAT is designed specifically to help states and local weatherization agencies implement the DOE Weatherization Assistance Program. NEAT can also be used with some limitations for small multifamily residences. NEAT evaluates each home individually after considering local weather conditions, retrofit measure costs, and specific construction details of the home. After describing envelope components, systems, and base load equipment (e.g., refrigerators, water heaters, lighting), NEAT produces a prioritized list of cost-effective weatherization measures customized for the dwelling being evaluated. The output includes estimates of the energy savings, cost savings, installation cost, and savings-to-investment ratio (SIR) for each recommended measure.

1.2 LITERATURE REVIEW

1.2.1 Future Weather Models

Future weather data has long been a cornerstone for impact assessments across various fields, including agriculture, hydrology and ecology where researchers kept working closely with climate scientists to develop a variety of methods and tools to generate future weather data as inputs for their models [Zeng et al., 2025]. Since the climate depended on many uncertain factors, the Intergovernmental Panel on Climate Change (IPCC) published four scenarios, A1, A2, B1 and B2 which are known as the Special Report on Emissions Scenarios (SRESs), in 2000 to capture the range of possible future development trajectories [O'Neill et al, 2020] [Chen et al., 2023]. A scenario was defined as a plausible description of how the future may evolve based on a coherent set of assumptions about key driving forces, such as socioeconomic, technological and environmental conditions. [Zeng et al., 2025]. After 2009, new scenarios were required to capture the latest socioeconomic and technological developments and to address the evolving needs of various end users [Moss et al., 2010]. Such new scenarios were labeled as "representative concentration pathways", where the word 'representative' signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. RCP has four scenarios as well, including a low-emission scenario (RCP 2.6), two medium stabilization scenarios (RCP 4.5/6) and a high-emission scenario (RCP 8.5). In each of the four RCPs, a radiative forcing, or increase from background radiation, is defined for the year 2100: 8.5W/m^2, 6W/m^2, 4.5W/m^2 and 2.6W/m^2 [Dias et al., 2020].

After RCP, Socio-Economic Pathways (SSPs) were then published in 2017.The SSPs refer to a set of five socio-economic pathways (SSP1 to SSP5) consisting of qualitative narratives and quantitative projections for population, education, urbanization, and economic development describing how the future might unfold. The main difference between these two sets is that the focus of the RCPs is on the emissions and radiative forcing aspect of the future, whereas the SSPs are focused on the socio-economic aspect of the future, including population growth, economic development, techno-logical advances and societal preferences for fuels. Therefore, SSPs and RCPs were often combined to form integrated scenarios [Riahi et al., 2017].

These scenarios consisting of underlying economic and climate mitigation conditions are used as inputs to the Global Climate Models or General Circulation Models (GCMs) to produce predictions of future weather across the globe [Bass et al., 2022, Bagherzadeh et al., 2025]. GCMs are the primary tool to project the evolution of the climate. They rely on a system of mathematical equations discretized on three-dimensional grids to simulate the movement of mass and energy throughout the atmosphere and oceans.

Relevant studies adopted various scenarios and corresponding climate models. SSP 5-8.5, which integrated SSP 5 and RCP 8.5, was selected to represent a scenario in which fossil fuels drive economic development in the coming years [Bass et al., 2022]. Such a scenario illustrates an upper bound for climate change impacts. Six different climate models projecting this scenario were used. The effects from future climate change on the phase change material integrated envelope performance were investigated [Wang et al., 2025]. In this study, four SSP scenarios were adopted, which were in the format of SSPx-y with x meaning socioeconomic trends set and y indicating the approximate level of radiative forcing in the year 2100. To better project future building energy demands and urban climate resilience, building energy modelling was conducted under assumed future microclimate. RCP 8.5 was used to represent an extreme climate scenario in this study. The impacts of future climate change on residential and office building energy usage pattern in the U.S. climate condition were evaluated [Shen, 2017]. One well-known GCM-HadCM3, which has high temperature sensitivity, was used to generate future weather files. A morphing method was also adopted for downscaling of the GCM. The selected weather scenarios were A1 and A2, which represent medium and worst carbon scenario, since the authors considered the current worldwide carbon emission was not quite optimistic. In contrast, a more optimistic assumption, the IPCC B1 scenario which represents a low-emission scenario, was assumed in another study for estimation of the weather change impact on the city-scale building energy consumption [Chen et al., 2023].

A Typical Meteorological Year, representing the weather at a location over a period of time, contains a year of hourly weather data consisting of the most representative months over the time period of interest. These representative months are concatenated to represent a typical year of weather for a given location, eliminating months and years that are considered to be outliers. The same method could be applied to develop Future Typical Meteorological Year (fTMY) weather data files or instead of being selected from one single future climate model, the representative months could be selected over several climate models to eliminate the model extreme variability [Bass et al., 2022]. The time length of the fTMY was chosen to be 20 years. In our study, the building energy models created using NEAT are simulated with future weather data. The results will be compared with those generated with TMY3 weather file as the input to estimate how future weather climate will impact building energy use in the selected climate zones.

1.2.2 Studies on Energy Use Impacts

It can be anticipated that the building energy performance in the future can be modelled more accurately through developments of the fTMYs. The impact of climate change on the building energy consumption will vary greatly according to geographical region and building types [Wang and Chen, 2014]. The following studies investigated the impact of emission scenarios and GCMs on building energy performance.

HadCM3 GCMs based on three IPCC scenarios (A1, A2 and B1) were used to generate fTMYs for 15 cities in the U.S. [Wang and Chen, 2014]. The energy simulation in each city included two types of residential buildings and seven types of commercial buildings. A morphing method was used to down-scale the monthly changes to hourly changes in the process of formatting fTMY files. The simulation results showed that the majority of the cities located in Climate Zones 1–4 would experience a net increase in source energy use for cooling and heating by the 2080s, while cities in Climate Zones 6 and 7 would experience a net reduction in source energy use. With 23 GCMs and four RCP scenarios (2.6, 4.5, 6.0 and 8.5), a study investigated the impact of GCM selection on the energy consumption of the same buildings [Zhai and Helman, 2019]. In this study, solar radiation change, and humidity change were not considered and RH was considered as constant, while hourly dry-bulb temperature was formed from average monthly temperature, average daily maximum temperature and average minimum temperature under a morphing algorithm. For the tested buildings, the heating energy decreased, and the cooling energy increased. The climate change impact on energy performance of buildings in Hong Kong was investigated with the GCM MIRCO3_2-MED and two IPCC scenarios (A1 and B1) [Chan, 2011]. The projected changes in dry-bulb temperature, wet-bulb temperature, solar radiation and rainfall were realized by a morphing approach. By running a typical set of simulated High-rise office and residential buildings, the results showed that there will be a substantial increase in the energy consumption of air-conditioning systems in this subtropical city. A study used a tool (CCWorldWeatherGen) to morph the GCM(s) with large-scale atmospheric variability into a regional climate model (RCM) with finer scale and higher resolution (i.e., 9km) [Dias et al., 2020]. The study focused on the Iberia Peninsula under the RCP8.5 emission scenario. The impact of different data sources as well as different methods for building one-year climate data files on the building energy simulation of four prototypes was studied. Under different TMY file inputs, the differences in annual and peak (hourly) energy consumption were often greater than 10%.

The cooling/heating degree day based (CDD or/and HDD) method are simple and common to analyze the impacts of climate change on building energy use [Zhai and Helman, 2019]. Degree days can be calculated based on hourly, daily (average daily temperatures or combined with minimum and maximum daily temperature) or monthly mean temperature data [Ramon et al., 2020]. The main principle of this method is that the building energy use is proportional to the heating and cooling degree days for the location of the building.

Using CDD and HDD as energy impact indicators, a study revealed that different climate models (even within the same RCP scenario) yield largely different results for building energy implications [Zhai and Helman, 2019]. Five typical US building types were selected in Ann Arbor, Mi to display the climate change impacts. This study uses 23 models with one or more scenarios for each model for a total of 56 model scenarios. Balance point temperatures of 10 °C and 18 °C were used for calculating CDD and HDD, respectively. The results showed that the dry bulb temperature changes had the largest impact on building energy consumption while RH had a considerable impact on extremely cold days only. Degree day method was also used to analyze the future climate change impact on German residential building energy consumption [Olonscheck et al., 2011]. The simulation results showed that there would be a strong decrease in heating energy demand but an increase in cooling demand. Heating energy demand would decline 44% to 78% and the corresponding cooling energy demand will increase by 59% to 25% depending on the selected scenarios when comparing the period 1961-1990 with 2031-2060.

2. METHODOLOGY

Figure 1 illustrates the input formulation process for NEAT, designed to enable simulation-based evaluation of future weather conditions. The process involves four key components: EPW2JSON Converter, Weather File, NEAT Engine, and Building Description. The EPW2JSON Converter transforms weather data from EPW format into JSON and performs necessary preprocessing, such as degree-hour calculations. The resulting Weather File contains all climate-related inputs required by the NEAT engine. The NEAT Engine, a pre-compiled tool, evaluates buildings energy use based on this weather data and building inputs. The Building Description is a JSON file defining the building envelope, mechanical systems (e.g., HVAC and water heating), and specifying the Weather File used in the simulation.

EPW files are standardized weather data files used primarily for building energy simulation. They contain detailed hourly weather information, such as dry-bulb temperature, relative humidity, solar radiation, wind speed and wind direction. Conversion to JSON involves more than reforming only; it generates additional derived inputs, such as degree-hours calculated from hourly outdoor temperatures, and interpolates missing data where necessary. In this study, two types of EPW files are used: TMY3 and fTMY dataset. The TMY3 dataset was developed by the National Renewable Energy Laboratory using historical data from 1961 to 1990. In contrast, the fTMY dataset was developed by Oak Ridge National Laboratory through downscaling six different global climate models (GCMs), and it represents projected future weather conditions for the period from 2020 to 2100 [Bass et al., 2022].

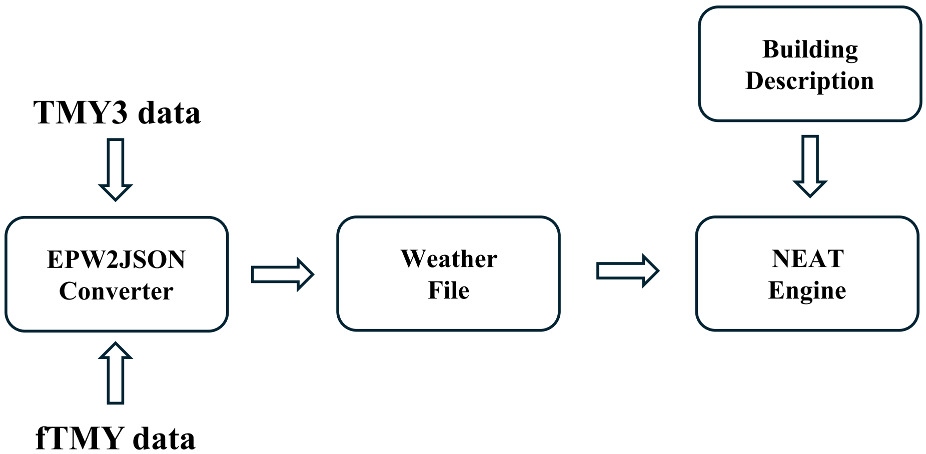

Figure 1. Software workflow for building performance in NEAT.

2.1 CLIMATE LOCATIONS

The study is conducted for seven climate locations corresponding to ASHRAE climate zones as listed in Table 1. TMY3 and fTMY hourly weather files were obtained from EnergyPlus building simulation software. For use with NEAT, they are converted to a format for use with NEAT which is a variable-based degree day model. This study first compares the weather characteristics represented by TMY3 vs fTMY using various weather parameters including monthly HDD65, CDD65, average (annual) dry-bulb ($T_{dry,ave}$, °F) and average (annual) wet-bulb temperatures ($T_{wet,ave}$, °F), average wind speed (*WS*, m/s). It was noted that solar radiation and design day characteristics are identical.

Table 1. Climate locations

ASHRAE Climate zone	Climate location	TMY3 specific characteristics					fTMY specific characteristics				
		HDD65	CDD65	*WS*	$T_{dry,ave}$	$T_{wet,ave}$	HDD65	CDD55	*WS*	$T_{dry,ave}$	$T_{wet,ave}$
1A	Miami Intl AP, FL	236	4,292	9.2	76.1	69.4	246	4,503	7.9	76.6	70.2
2A	Lufkin-Angelina Co AP, TX	2,147	2,554	6.8	66.1	60.2	2,068	3,127	9.8	67.8	59.9
2B	Phoenix-Sky Harbor Intl AP, AZ	1,254	4,847	6.2	74.8	56.0	1,306	4,787	4.6	74.5	57.5
3A	DeKalb-Peachtree AP, GA	3,547	1,810	6.3	60.2	53.6	3,011	2,187	7.9	62.7	55.8
3B-Coast	Burbank-Hope AP, CA	2,483	3,469	5.4	64.0	55.1	2,228	3,809	5.2	66.2	52.7
3B	Las Vegas-McCarran Intl AP, NV	1,893	1,563	10.0	67.6	49.3	1,406	1,845	8.3	69.2	52.1
3C	San Francisco Intl AP, CA	3,191	209	10.4	56.8	51.6	3,131	399	7.4	57.5	48.0
4A	Baltimore-Washington	4,735	1,368	8.8	55.7	48.9	4,575	1,546	8.4	56.6	50.4

	Intl Marshall AP, MD										
4B	Albuquerque Intl Sunport, NM	4,509	1,449	8.7	56.5	44.3	4,382	1,795	8.3	57.8	44.1
4C	Renton Muni AP, WA	4,642	374	6.4	53.2	48.0	4,807	435	9.1	53.0	47.0
5A	Chicago Midway Intl AP, IL	5,825	1,260	10.2	52.4	45.9	5,844	1,179	9.9	52.1	46.3
6A	Minneapolis-Crystal AP, MN	8,387	779	7.9	44.0	38.5	7,416	956	9.0	47.2	41.2
6B	Helena Rgnl AP, MT	7,898	559	7.3	44.8	36.8	7,301	809	10.1	47.1	37.8
7	Eveleth-Virginia Muni AP, MN	9,988	493	6.5	38.9	34.4	9,382	508	10.9	40.5	34.3

2.2 BUILDING ENERGY MODEL

The study uses NEAT (National Energy Audit Tool), developed by ORNL for the US Department of Energy's Weatherization Assistant Program (WAP). NEAT has been widely used for weatherizing site-built, single-family homes, and validated against utility bills and DOE-2.1E simulation program [Gettings 2003, Gettings et al., 1998]. NEAT's engineering algorithms are based on those developed for Lawrence Berkeley Laboratory's Computerized Instrumented Residential Audit (CIRA) [Sonderegger et al., 1982]. It uses variable-based degree hour method to predict energy use and savings from weatherization measures.

The analysis in this study is based on the definition of DOE single-family prototype building model, which is a 2400 ft^2, two-story, 3-bedroom, detached home [Mendon et al., 2013]. The building has a wood-frame structure with a vented attic. Four variations of the foundation of prototype model are defined: slab-on-grade, crawlspace, unheated basement, and heated basement. Figure 2 shows the building with a crawlspace foundation configuration. The building has a 15% window-to-floor ratio (WFR) distributed equally along all cardinal directions with no exterior shading.

For modeling the building in NEAT, the overall building geometry, construction, and system specifications are adopted from [Mendon et al., 2013]. The thermal characteristics of the envelope are adopted from IECC 2000 to represent conditions typical of older housing stock. NEAT does not explicitly model attic and foundation spaces but uses energy balance of vented attic space and foundation space to calculate effective UA. NEAT's default internal gain of 2500 Btu/hr is used, which is based on assumptions about major appliances and lighting [Gettings, 2003].

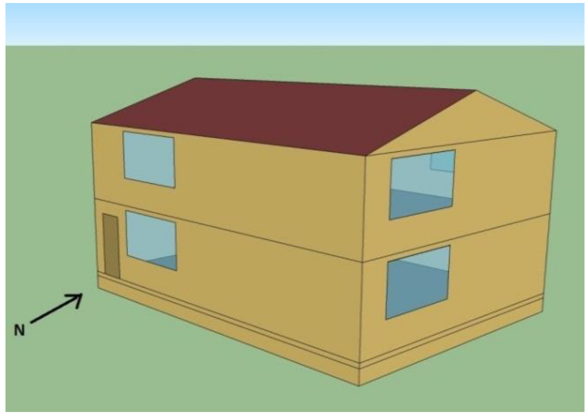

Figure 2. DOE single-family prototype with a crawlspace foundation configuration [Mendon et al., 2013].

3. RESULT ANALYSIS

3.1 fTMY CHARACTERISTICS COMPARED TO TMY3

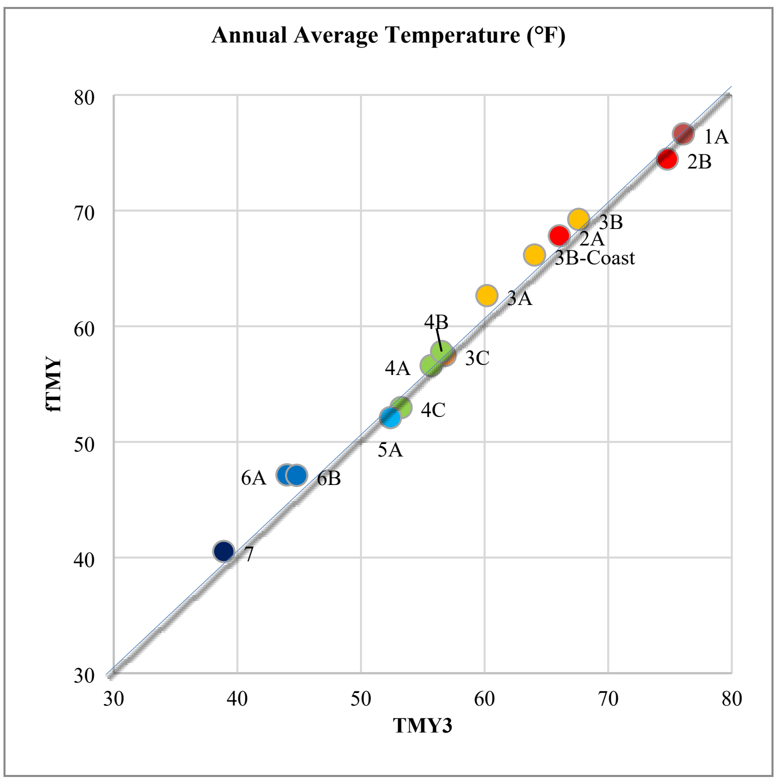

Figure 3. Comparison of annual average temperature for selected climate locations.

Figure 3 presented a comparison of annual average temperature under TMY3 and fTMY for the selected climate locations. In most locations, fTMY exhibits higher annual average temperatures than TMY3, reflecting projected future warming trends. Three exceptions are observed in Phoenix-Sky Harbor International Airport (climate zone 2B), Renton Municipal Airport (zone 4C), and Chicago Midway International Airport (zone 5A) where the average temperature under fTMY is slightly lower. This general pattern is consistent with established expectations of global climate warming.

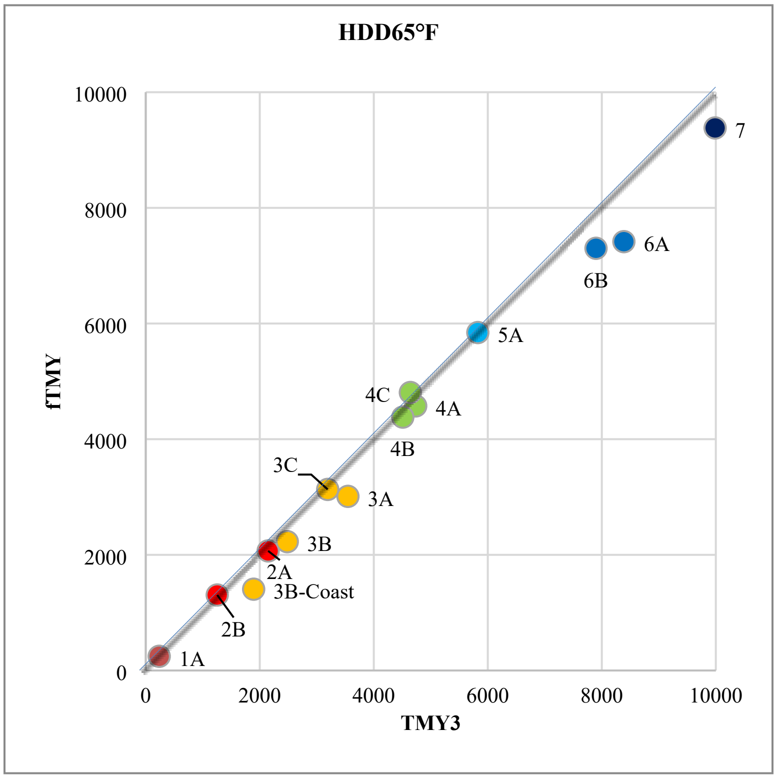

Figure 4. Comparison of heating degree days for selected climate locations.

As shown in Figure 4, heating degree days with 65degF as the balance temperature (HDD65degF) are generally lower under fTMY than those under TMY3, especially for the colder regions such as Minneapolis-Crystal Airport, MN (zone 6A), Helena Regional Airport, MT (zone 6B), and Eveleth-Virginia Municipal Airport, MN (zone 7). This may suggest that future climate conditions could lead to modest reductions in winter heating demand in these northern zones, as reflected by the decreased HDD65 values.

Figure 5 displays the cooling degree days (CDD65) for the selected locations. Across most climate zones, the CDD values were higher under fTMY, indicating a greater need for cooling energy in the future. This trend reinforces the expectation that rising temperatures will elevate summer thermal demands in many parts of the United States.

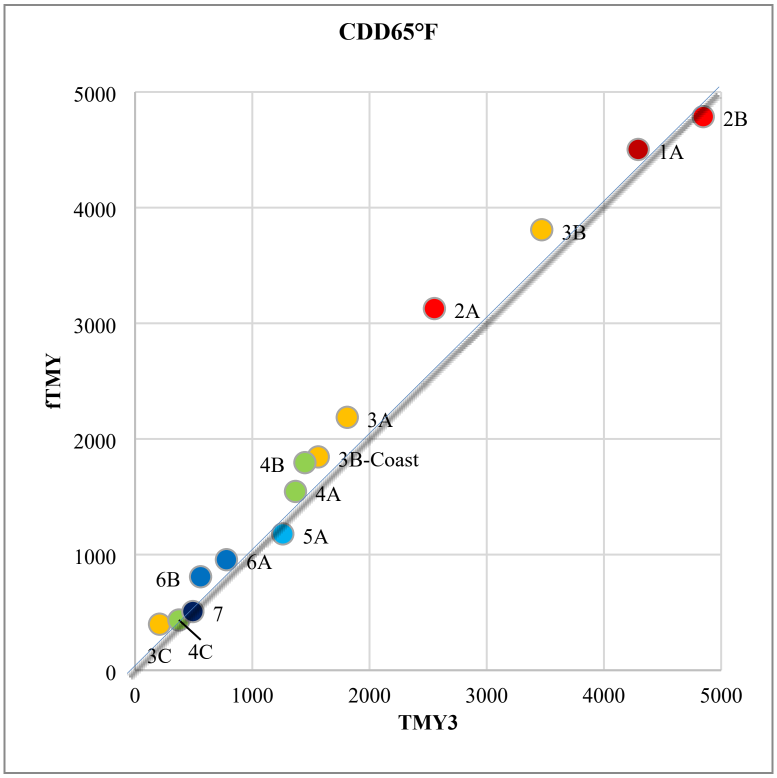

Figure 5. Comparison of cooling degree days for selected climate locations.

3.2 IMPACT ON ANNUAL LOADS

In our study, four heating system types were considered, which are heat pump (HP), gas furnace (GF), oil furnace (OF) and electric furnace (EF). Four foundation types were considered, which are slab (Slab), crawlspace (Crsp), unconditioned (BsmU) and conditioned basement (BsmC). The annual heating and annual cooling energy (with the unit as MMBtu/yr) were not impacted by the selected heating system but were impacted by the selected foundation types. The following figures show the required annual heating and cooling loads under current weather conditions and future weather conditions (TMY3 and fTMY as inputs to NEAT, respectively).

Figures 6 to 9 show the results under the gas furnace heating system with different foundation systems. Figures 10 to 13 show the results under the electric furnace heating system with different foundation systems. Figures 14 to 17 show the results under the heat pump heating system with different foundation systems. Figures 18 to 21 show the results under the oil furnace heating system with different foundation systems.

While annual heating and cooling loads were sensitive to the type of foundation, the choice of heating system did not affect the modeled energy use in NEAT. Therefore, we focused our analysis on one representative heating system (i.e., gas furnace) across the four foundation types.

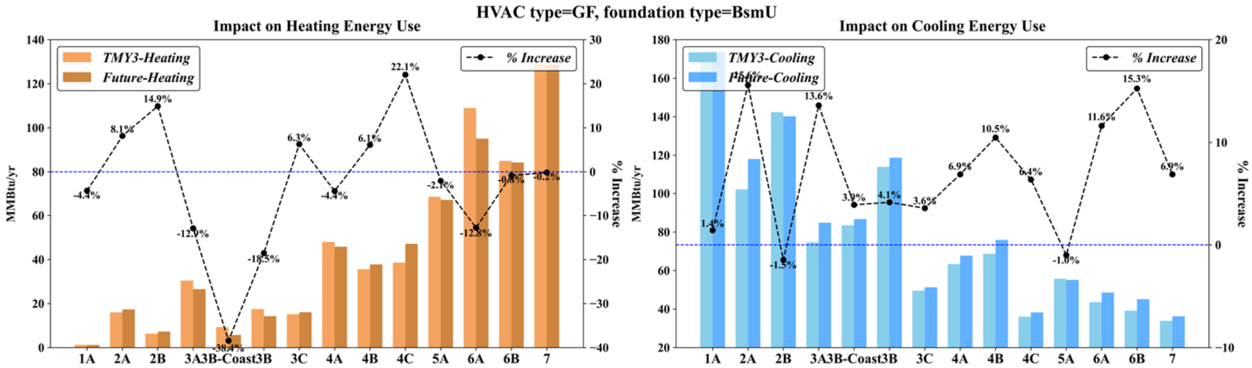

Figure 6. Annual heating and cooling loads for the selected climate locations (Scenario: gas furnace, unconditioned basement).

As shown in Figure 6 (gas furnace with unconditioned basement), five of the selected locations exhibited increased heating loads under future weather conditions, while the remaining locations showed decreases. On average, the heating load decreased by 2.6% across all locations. Notably, regions with mild winters, such as 3A (DeKalb, GA), 3B-Coast (Burbank, CA) and 3B (Las Vegas, NV), experienced the largest reductions, suggesting that heating load in locations with milder winter may decline more noticeably due to climate warming. In contrast, the cooling loads increase in most selected locations, with only 2B (Phoenix, AZ) and 5A (Chicago, IL) have showing minor decreases. The average increase in cooling load was 6.9%, with the most significant rises observed in 2A (Lufkin, TX), 3A (DeKalb, GA) and 6B (Helena, MT).

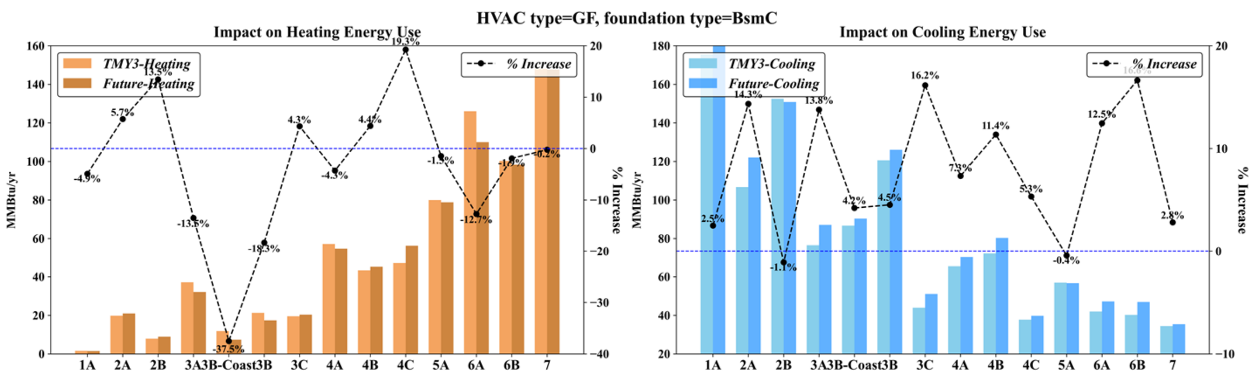

Figure 7. Annual heating and cooling load for selected climate locations (Scenario: gas furnace, conditioned basement).

Figure 7 represents the results for the same heating system with a conditioned basement foundation. Compared with the previous scenario, most locations showed similar trends in heating and cooling load changes. The average heating load reduction was slightly larger, at 3.4%. An exception was observed in climate zone 3C (San Francisco, CA), where the increase in cooling load rose sharply from 3.6% to 16.2%, making it the second-highest increase among all locations in this scenario.

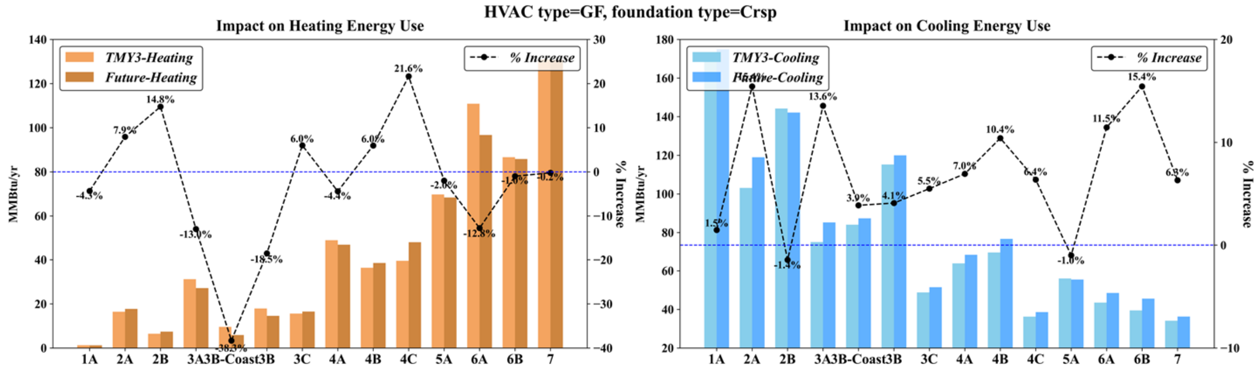

Figure 8. Annual heating and cooling load for selected climate locations (Scenario: gas furnace, crawlspace).

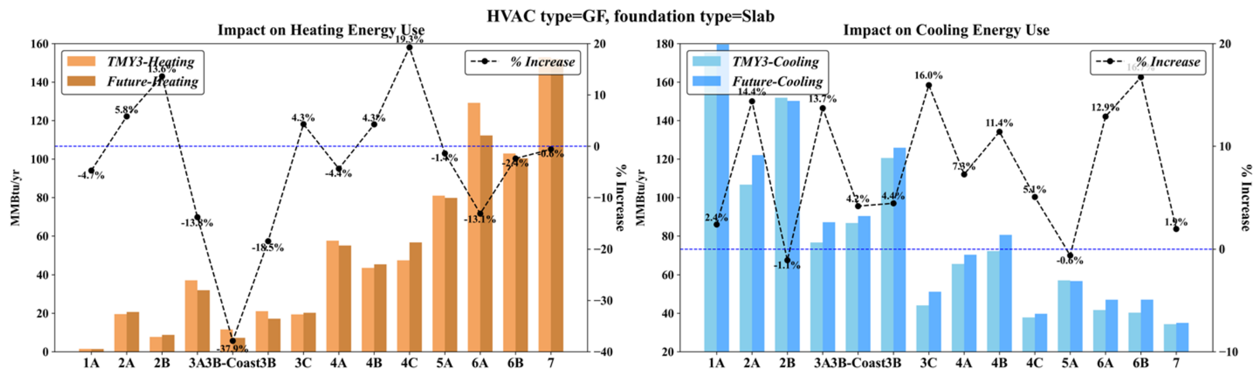

Figure 9. Annual cooling load for selected climate locations (Scenario: gas furnace, slab).

In the slab foundation scenario (Figure 8), heating and cooling load trends were largely consistent with those of the unconditioned basement case (Figure 6), with average changes of -2.7% for heating and +7.0% for cooling. Climate zone 3C again exhibited a cooling load increase of approximately 5.5%, similar to its performance in the unconditioned basement case.

Figure 9 shows the results for the crawlspace foundation scenario, which closely resembled the conditioned basement scenario (Figure 7). The average changes were -3.5% for heating load and 7.8% for cooling load, with climate zone 3C again showing a significant 16% increase in cooling demand.

Among these four foundation configurations, zones 3A (DeKalb**,** GA) and 6A (Minneapolis, MN) demonstrated relatively balanced thermal shifts, where the percentage decrease in heating load was roughly offset by the percentage increase in cooling load. In contrast, locations such as 2A (Lufkin, TX), 4B (Albuquerque, NM), and 4C (Renton, WA) showed increases in both cooling and heating loads, indicating more complex regional responses. Zone 5A (Chicago, IL) remained relatively stable across all scenarios, with minimal changes in both heating and cooling loads.

Overall, the NEAT simulation results indicate that a consistent trend across climate zones: future weather conditions modeled with fTMY lead to higher cooling energy needs and lower heating energy needs, which aligns with the expected impacts of climate change.

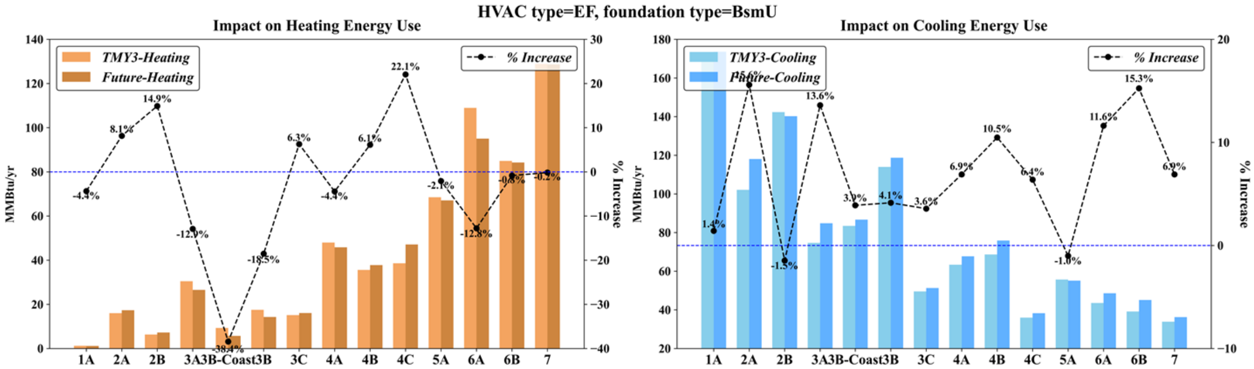

Figure 10. Annual heating and cooling loads for the selected climate locations (Scenario: electric furnace, unconditioned basement).

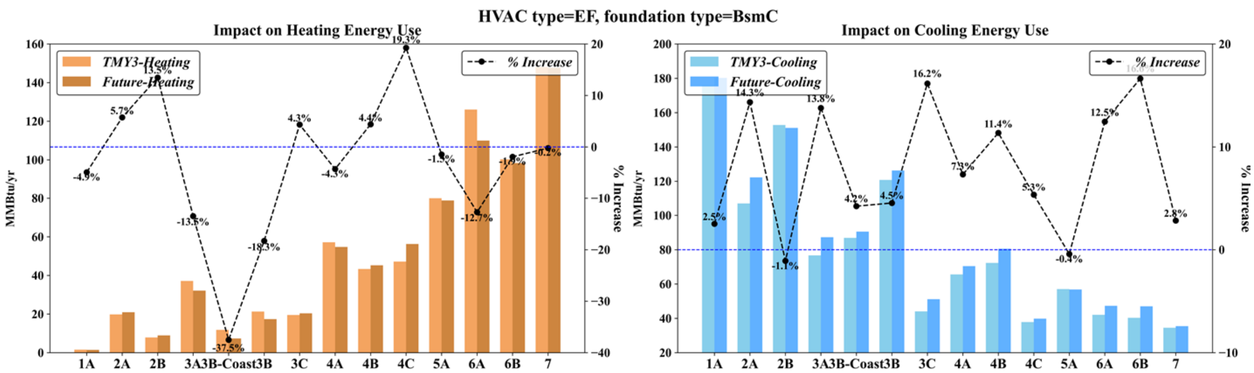

Figure 11. Annual heating and cooling loads for the selected climate locations (Scenario: electric furnace, conditioned basement).

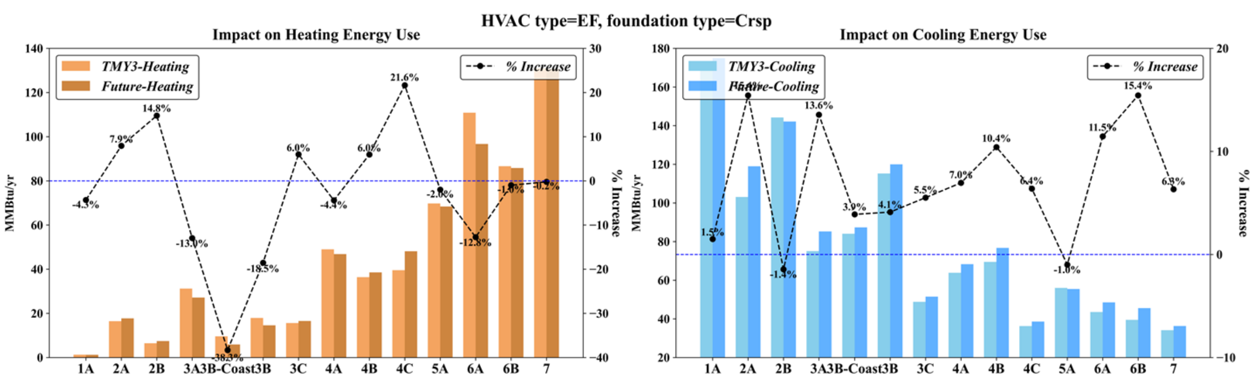

Figure 12. Annual heating and cooling loads for the selected climate locations (Scenario: electric furnace, crawlspace).

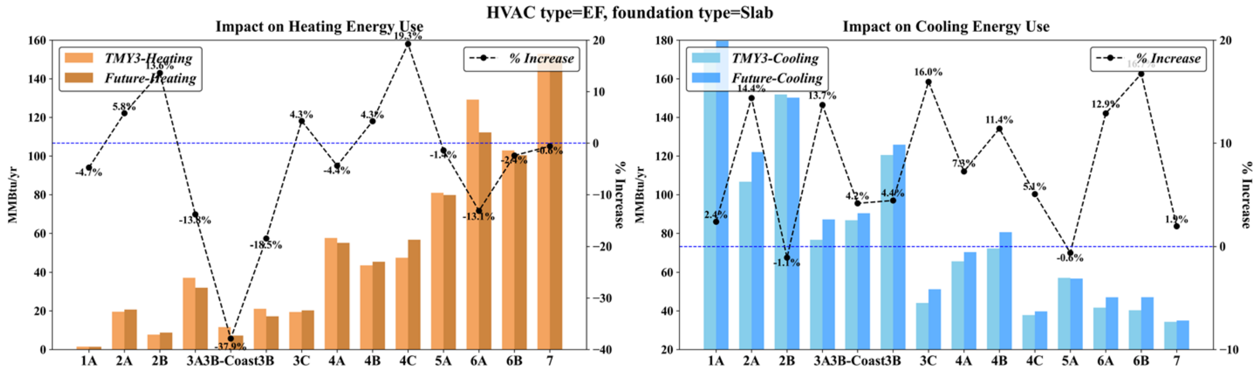

Figure 13. Annual heating and cooling loads for the selected climate locations (Scenario: electric furnace, slab).

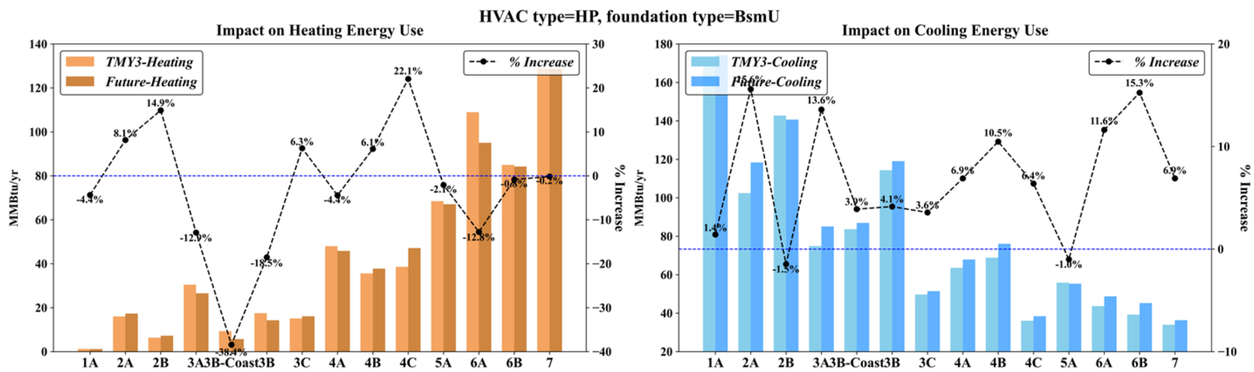

Figure 14. Annual heating and cooling loads for the selected climate locations (Scenario: heat pump, unconditioned basement).

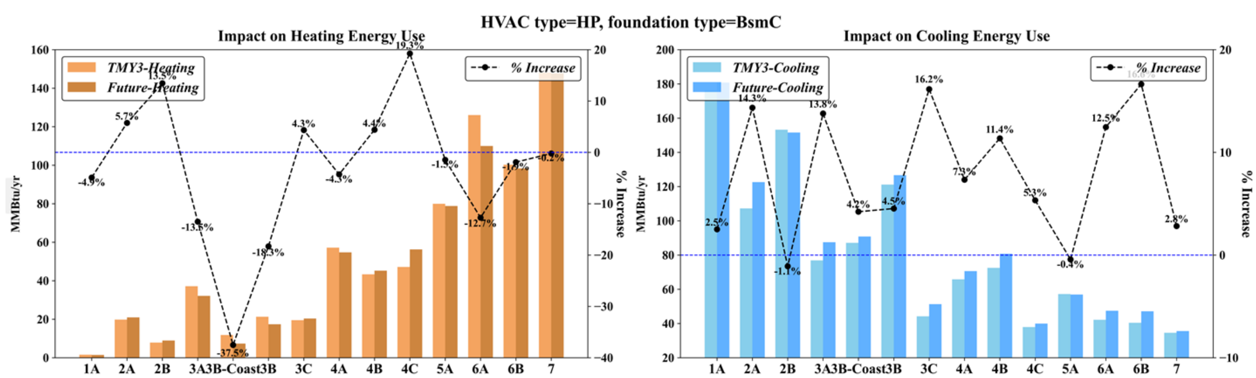

Figure 15. Annual heating and cooling loads for the selected climate locations (Scenario: heat pump, conditioned basement).

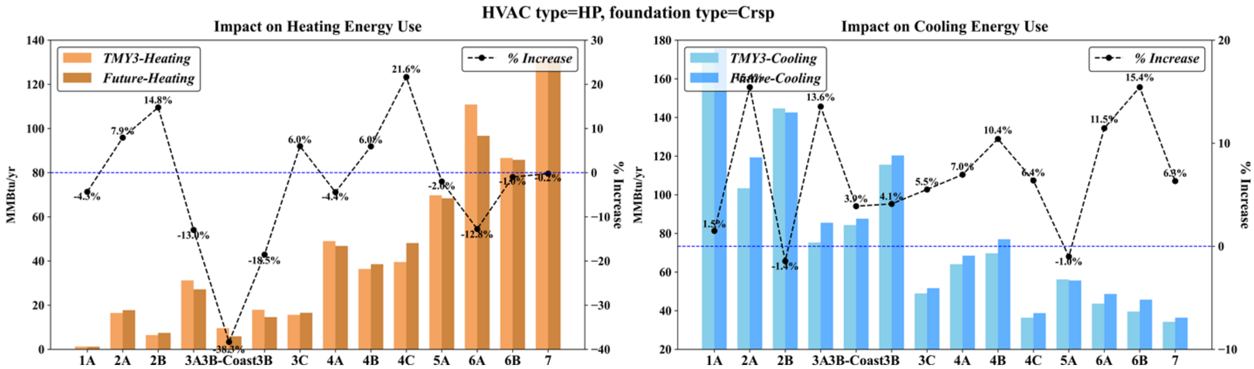

Figure 16. Annual heating and cooling loads for the selected climate locations (Scenario: heat pump, crawlspace).

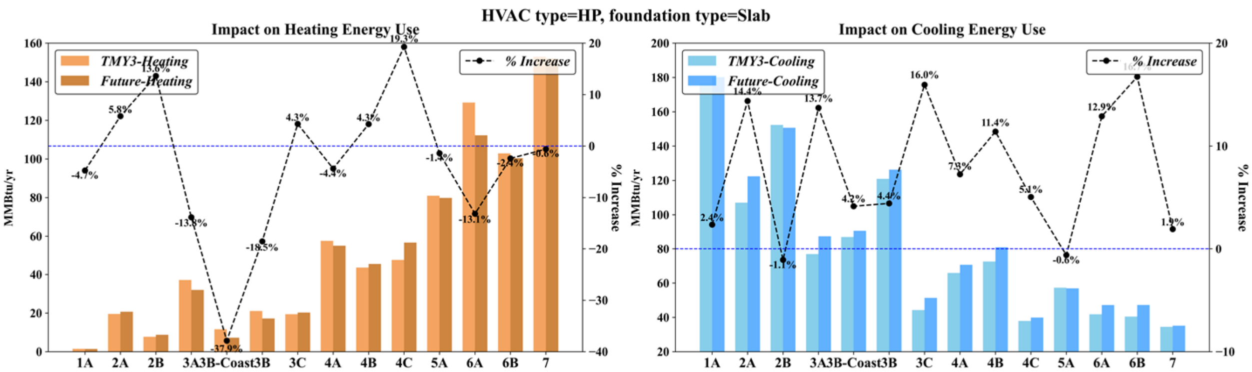

Figure 17. Annual heating and cooling loads for the selected climate locations (Scenario: heat pump, slab).

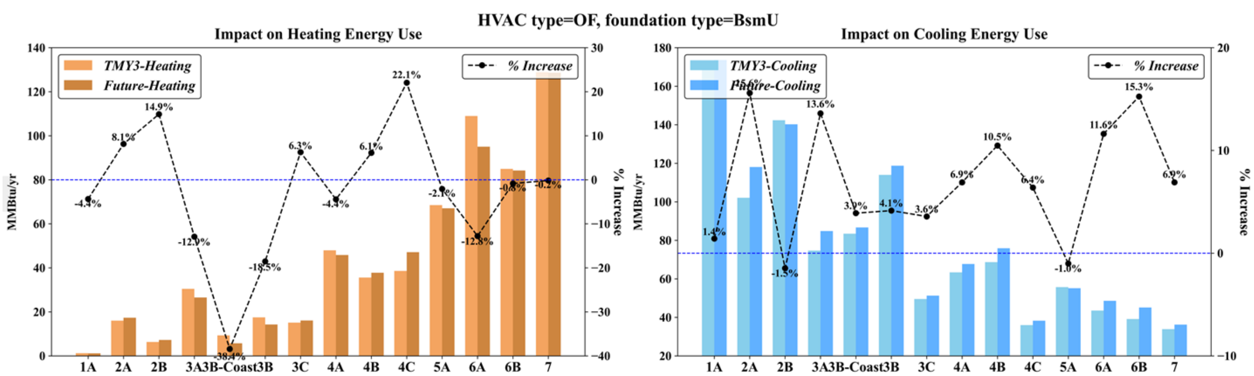

Figure 18. Annual heating and cooling loads for the selected climate locations (Scenario: oil furnace, unconditioned basement).

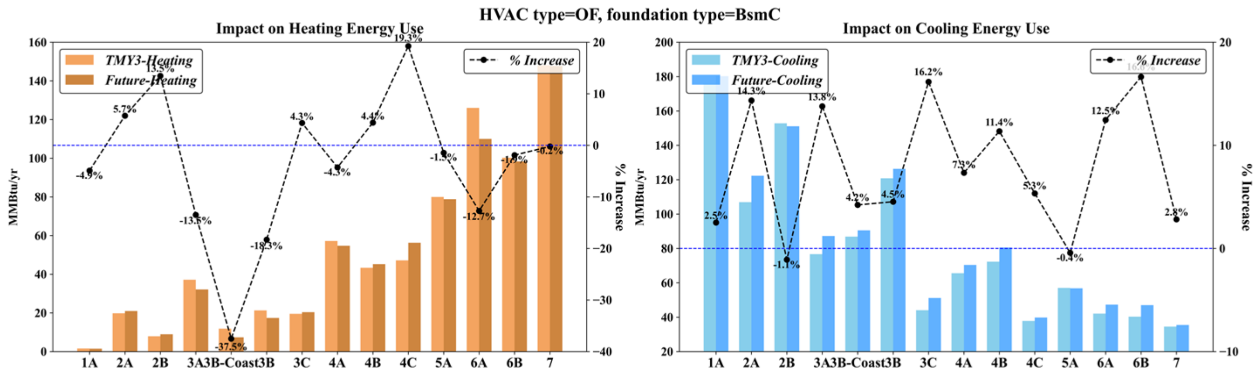

Figure 19. Annual heating and cooling loads for the selected climate locations (Scenario: oil furnace, conditioned basement).

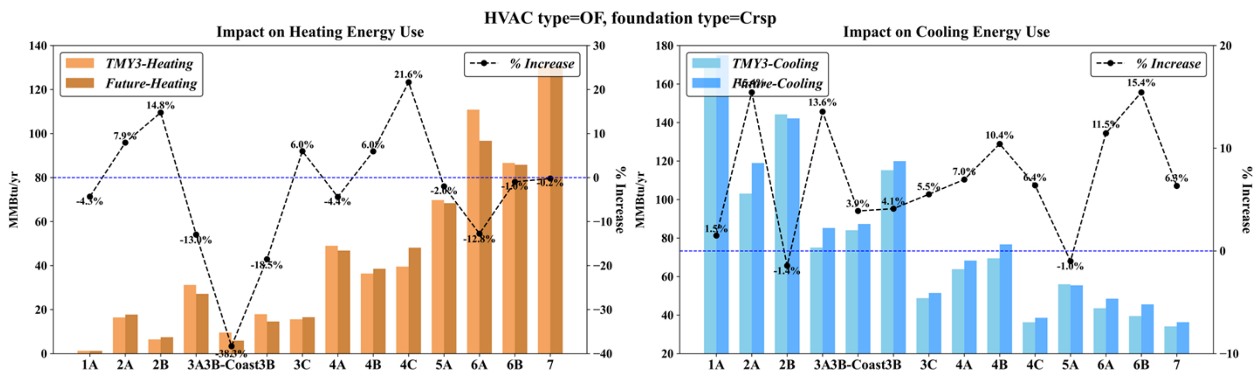

Figure 20. Annual heating and cooling loads for the selected climate locations (Scenario: oil furnace, crawlspace).

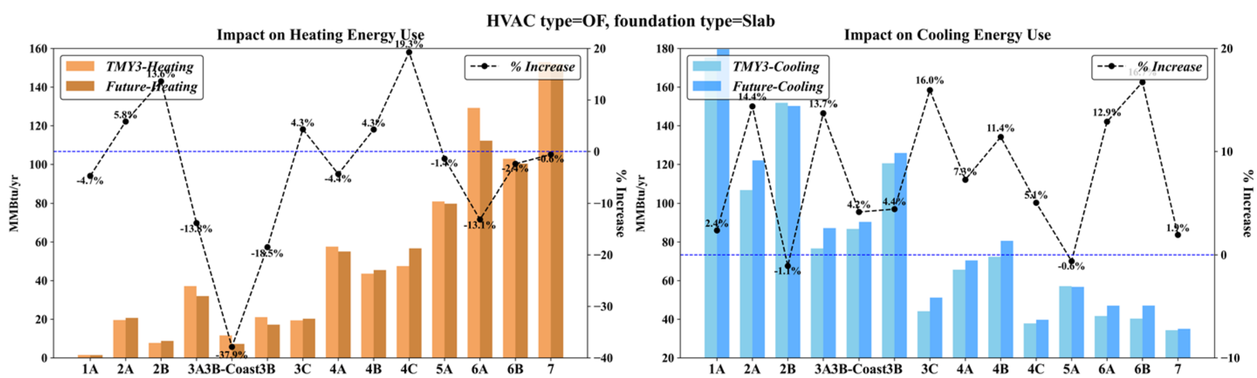

Figure 21. Annual heating and cooling loads for the selected climate locations (Scenario: oil furnace, slab).

4. CONCLUSIONS

This study supports the mission of the WAP by evaluating how projected future climate conditions may affect residential building energy performance. Specifically, we assess the impact of using future typical meteorological year (fTMY) weather files, derived from global climate model (GCM) projections, on baseline energy use in single-family homes. While the long-term objective is to understand how future climate may influence the cost-effectiveness of weatherization measures, this report focuses on a critical preliminary step: comparing baseline building thermal loads modeled under fTMY versus the historically based TMY3 weather files currently used in WAP audit tools.

Weather characteristics derived from fTMY files show clear shifts relative to TMY3. For most locations, annual average temperatures are higher under fTMY, consistent with projected global warming trends. Notably, heating degree days (HDD65) are generally lower under fTMY, especially in colder climate zones such 6A, 6B and 7, which indicates a potential heating demand reduction in the future. Conversely, cooling degree days (CDD65) increase across nearly all locations, suggesting increased cooling needs in the coming decades.

The comparison of annual thermal energy loads under TMY3 and fTMY was conducted for various combinations of heating systems and foundation types. Since NEAT does not differentiate cooling/heating loads under various heating system types, results were analyzed based on one single representative system (i.e., gas furnace) across four foundation types. Across all scenarios, a consistent pattern emerged: future weather conditions led to reduced heating loads and increased cooling loads for most locations. For instance, mild climate zones such as 3A (DeKalb, GA), 3B-Coast (Burbank, CA) and 3B (Las Vegas, NV) showed the most significant reductions in heating load, while cooling load increases significantly in zones such as 2A (Lufkin, TX), 3A (DeKalb, GA) and 6B (Helena, MT). Climate zone 3C (San Francisco, CA) showed sensitivity to foundation type, with cooling load increases ranging from moderate to over 16% depending on configuration.

Although retrofit measures were not directly analyzed in this phase of the project, the observed shifts in baseline loads underscores the importance of integrating future weather data into energy modeling tools like NEAT.

In summary, this study establishes that the use of future climate data meaningfully alters modeled building energy loads. These findings lay a quantitative foundation for future work that will assess how such changes affect the performance and cost-effectiveness of energy efficient retrofit measures. Incorporating fTMY into weatherization audits represents an evolution in modeling practices to ensure that programs like WAP continue to use inputs that appropriately reflect future conditions and ensure persistent energy savings and cost-effectiveness.

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