FINAL REPORT

X1931-7 PSD HDD/CDD Update Study

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ABSTRACT

As part of the ongoing project “X1931 CT Program Savings Document (PSD) Review and Update,” the Connecticut Energy Efficiency Board (EEB) Evaluation Administrators commissioned DNV to update the heating degree day (HDD) and cooling degree day (CDD) values in the PSD. This report presents the methods and results of research to quantify statewide, utility-specific, and regional (inland/coastal) degree day values that represent recent climatological trends among all ten weather stations in Connecticut. The PSD uses degree-day values to estimate annual energy impacts from residential weatherization measures such as insulation. We recommend that the next versions of the PSD replace the preexisting degree day values with this study’s regional (inland/coastal) values. In parallel with the PSD update, Eversource and United Illuminating should revise all affected savings calculators and tracking systems to incorporate inland/coastal degree day values based on project location. Should that option not be feasible, we recommend that the PSD and utilities incorporate utility-specific degree day values.

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1 EXECUTIVE SUMMARY

This report presents the results of primary research to update the heating degree day (HDD) and cooling degree day (CDD) values recommended in the Connecticut Program Savings Document (PSD). This research study was commissioned by the Connecticut Energy Efficiency Board (EEB) Evaluation Administrators (EA) as part of the ongoing project X1931 PSD Review and Update project. The 2021 PSD recommends a single set of statewide HDD and CDD values, which were developed using historical (1978-2008) weather data of the Hartford weather station. The objective of this research study is to update the PSD's recommended HDD and CDD values to reflect more recent climatological trends among all weather stations in CT.

1.1 Key Findings

This study involved recalculation of HDD and CDD values based on 2005-2020 weather data of ten Connecticut weather stations listed on the National Oceanic and Atmospheric Administration's (NOAA) website[1]. The PSD primarily uses HDD and CDD values in the savings estimation for residential weatherization measures such as insulation. DNV developed statewide, utility-specific, and regional (inland/coastal) HDD and CDD values representative of the state's ten weather stations based on residential population weighting. As shown in Table 1-1 and Table 1-2, the updated statewide HDD and CDD values are 7% lower and 28% higher than the HDD and CDD values recommended in the 2021 version of the PSD, respectively. Notably, we found key differences in HDD and CDD values between inland and coastal regions, reflecting the climatological differences in those regions.

Table 1-1. 2021 CT PSD HDD values and updated HDD values

Description	CT PSD HDD Values	Updated HDD Values	% Difference	ASHRAE Adjustment Factor (F_{adj})
Statewide	5,885	5,362	-8.9%	0.61
Eversource	5,885	5,473	-7.0%	0.61
UI	5,885	5,165	-12.2%	0.60
Inland	5,885	5,578	-5.2%	0.61
Coastal	5,885	5,019	-14.7%	0.60

Table 1-2. 2021 CT PSD CDD values and updated CDD values

Description	CT PSD CDD Values	Updated CDD Values	% Difference
Statewide	603	772	28.0%
Eversource	603	757	25.5%
UI	603	864	43.3%
Inland	603	740	22.7%
Coastal	603	823	36.5%

1.2 Recommendations

To best characterize the weather-dependent impacts of measures such as residential weatherization, we recommend that future versions of the PSD adopt the inland/coastal HDD and CDD values and the corresponding ASHRAE adjustment factor values presented in this study. We acknowledge that adoption of two different HDD and CDD values may introduce complexity within the utilities' tracking systems. As an alternative, we recommend that the PSD

[1] Accessed online at https://www.ncdc.noaa.gov/cdo-web/datatools/lcd.

adopts utility-specific HDD and CDD (and the corresponding ASHRAE adjustment factor) values as presented in Table 1-1 and Table 1-2.

The HDD and CDD values should be updated in the sections of the PSD listed in Table 1-3.

Table 1-3. Recommended changes in the PSD

Description	PSD Reference	Action
Insulate Attic Openings, Residential	Page 242, Table 4-WWW	Update HDD and ASHRAE adjustment factor (F_{adj}) value
Wall Insulation, Residential	Page 251, Table 4-IIII	Update HDD and ASHRAE adjustment factor (F_{adj}) value
Ceiling Insulation, Residential	Page 258, Table 4-LLLL	Update HDD and ASHRAE adjustment factor (F_{adj}) value
Floor Insulation, Residential	Page 264, Table 4-OOOO	Update HDD and ASHRAE adjustment factor (F_{adj}) value
Kitchen Hood Controls, Commercial	Custom spreadsheet	Update HDD and CDD values
Appendix Seven	Page 332-333, Table A7-1: Abbreviations and Acronyms	Update HDD and CDD values

2 INTRODUCTION

The CT PSD expresses annual operation in terms of HDDs and CDDs for five weather-dependent measures, such as attic insulation, wall insulation, and duct sealing, as shown in Table 2-1.

Table 2-1. Measures in the PSD affected by the HDD and CDD values

Measures Affected	Equation in the PSD
Insulate Attic Openings, Residential	$ABTU_{Conductive} = A \times \left(\frac{1}{R_e} - \frac{1}{R_i} \right) \times HDD \times 24 \frac{hrs}{day} \times F_{adj}$
Wall Insulation, Residential	$ABTU_{Conductive} = A \times \left(\frac{1}{R_e} - \frac{1}{R_i} \right) \times HDD \times 24 \frac{hrs}{day} \times F_{adj}$
Ceiling Insulation, Residential	$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A$
Floor Insulation, Residential	$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A \times GF$
Kitchen Hood Controls, Commercial	HDD and CDD values are used as inputs in the savings calculation spreadsheet

As is standard in technical resource manuals (TRMs) for other jurisdictions, the HDD and CDD values should be calculated based on reasonably proximate weather data to accurately estimate the annual energy impacts of weather-dependent measures. The PSD currently recommends single, statewide HDD and CDD values that were developed using 1978 – 2008 average historical weather data of only one climatic zone in CT. The R91 impact evaluation best practices study[2] determined that the statewide HDD and CDD values presented in the PSD most closely align with Hartford (inland) climate but not the coastal regions where significant program participation was determined. DNV initially estimated that the inland HDD values are 10% higher compared to coastal HDD values and the inland CDD values are 12% lower than coastal CDD values. By assuming inland HDD and CDD values for statewide measure savings estimations, the PSD is overestimating heating and understanding cooling savings of the state's residential weatherization measures.

Weather data in the last decade has deviated from the 1978-2008 averages, trending warmer as a likely result of climate change. This study not only investigated the differences in Connecticut weather across its ten inland and coastal weather stations but also updated the DD values to reflect more recent climatological trends of those ten weather stations using historical 2005-2020 weather data.

2.1 Study Objectives

The primary objectives of this project were to:

1. Revise HDD and CDD values based on the most recent climate data reflective of all 10 weather stations in Connecticut

[2] NMR Group Inc, Review of Impact Evaluation Best Practices Final Report (R91), March 30, 2016. Accessed online at https://www.energizect.com/sites/default/files/R91%20-%20Review%20of%20Impact%20Evaluation%20Best%20Practices_Final%20Report_3.30.16.pdf

2. Develop alternative options for Connecticut utilities to incorporate revised HDD/CDD values most seamlessly in their respective tracking databases.
    a. Develop a single statewide set of weighted HDD and CDD values.
    b. Develop separate HDD and CDD values for inland and coastal regions
    c. Develop utility-specific HDD and CDD values.

3 METHODOLOGY

This section describes the methodologies that DNV used to revise the degree day values. This study primarily involved gathering and processing climate data, developing weights based on state population data, and analyzing the weighted HDD/CDD values by region, by utility, and statewide. Each task completed in this study is presented in following subsections.

3.1 Weather Data Collection and Processing

DNV gathered 2005-2020 hourly outside air temperature data for Connecticut's ten weather stations listed on NOAA's website[3]. We averaged the 16-year hourly temperature data to calculate annual average hourly temperature data for each station. Assuming a base temperature of 65°F to be consistent with prior DD values, we developed annual average HDD and CDD values for each weather station from the annual average hourly temperature data. We then weighted the annual average HDD and CDD values across the ten stations as described in the next subsection.

3.2 Weighting Among Different Weather Stations

DNV initially investigated the use of prior Home Energy Services (HES) and HES-Income Eligible (IE) program participation data for residential weatherization measures as possible weighting variables among the ten weather stations. Upon retrieving HES and HES-IE program participation data in 2019, DNV determined significant variation in program activity by region. As a result, DNV used census-based residential population data mapped to each weather station as the weighting variable, as described in the next paragraphs.

Table 3-1. Residential population and degree day values by weather stations

Weather Station	Total Residential Population	HDD 65°F	CDD 65°F
Chester Airport	129,479	5,432	702
Danbury Municipal	250,883	5,685	636
Groton New London Airport	168,413	5,175	593
Hartford Bradley Intl Airport	310,466	5,636	814
Hartford Brainard Field	577,968	5,319	875
Igor I Sikorsky Memorial	728,735	4,924	888
Meriden Markham	428,902	5,493	749
New Haven Tweed	372,366	4,993	841
Oxford Waterbury	363,283	5,933	557
Willimantic Windham	275,464	5,627	693
Total	**3,605,959**	**5,422 (Average)**	**735 (Average)**

We gathered population data for all 281 ZIP codes in Connecticut[4]. Each ZIP code was assigned one of the ten weather stations based on proximity via longitudinal and latitudinal mapping. We next calculated weights for each weather station based on its share of statewide residential population. Lastly, to calculate statewide weighted HDD and CDD values, we multiplied the population weights with the weather stations' corresponding HDD/CDD values and summed across all ten weather stations.

[3] Accessed online at https://www.ncdc.noaa.gov/cdo-web/datatools/lcd.

[4] Accessed online at https://www.connecticut-demographics.com/zip_codes_by_population

To calculate weights for inland and coastal HDD/CDD values, we first categorized each weather station as either "inland" or "coastal" based on proximity to the ocean. We then calculated the inland and coastal HDD and CDD values similarly to statewide but distinguished by the inland/coastal classification.

To calculate weights for utility-specific (Eversource vs UI) HDD and CDD values, we associated each of the state's 281 ZIP codes with a primary utility (Eversource or UI[5]) for each zip code in CT based on gas service territory maps. We then calculated population weights for each weather station between Eversource and UI designations. The population percentage weights were then used as the weighting variable for utility-specific HDD and CDD calculations.

The statewide, utility-specific, and regional HDD and CDD weights for the ten CT weather stations are shown in Table 3-2.

Table 3-2. Statewide, utility-specific, and regional HDD and CDD weights for CT weather stations

		Eversource		UI		Inland		Coastal	
Weather Station	Statewide Weights	HDD Weight	CDD Weight	HDD weight	CDD weight	HDD Weight	CDD Weight	HDD Weight	CDD Weight
Chester Airport	3.6%	0.3%	4.4%	4.1%	0.0%	0.0%	0.0%	9.3%	9.3%
Danbury Municipal	7.0%	13.0%	8.4%	1.1%	0.0%	11.4%	11.4%	0.0%	0.0%
Groton New London Airport	4.7%	2.5%	5.7%	0.0%	0.0%	0.0%	0.0%	12.0%	12.0%
Hartford Bradley Intl Airport	8.6%	7.1%	9.4%	9.0%	0.0%	14.1%	14.1%	0.0%	0.0%
Hartford Brainard Field	16.0%	6.5%	19.4%	25.9%	0.0%	26.2%	26.2%	0.0%	0.0%
Igor I Sikorsky Memorial	20.2%	23.1%	11.2%	41.5%	77.4%	0.0%	0.0%	52.1%	52.1%
Meriden Markham	11.9%	18.6%	12.3%	4.1%	3.7%	19.4%	19.4%	0.0%	0.0%
New Haven Tweed	10.3%	0.9%	9.9%	12.3%	15.2%	0.0%	0.0%	26.6%	26.6%
Oxford Waterbury	10.1%	20.5%	11.6%	0.0%	3.7%	16.5%	16.5%	0.0%	0.0%
Willimantic Windham	7.6%	7.5%	7.7%	1.9%	0.0%	12.5%	12.5%	0.0%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

[5] The UI classification included Southern Connecticut Gas and Connecticut Natural Gas.

4 RESULTS

Revised HDD and CDD values are presented below for statewide, utility, and inland/coastal classifications.

4.1 Statewide HDD and CDD Values

The PSD currently reports a single set of statewide HDD and CDD values, which were calculated using 1978-2008 weather data for the inland climate zone. Using the methods described in Section 2, we determined an HDD value 9% lower than the current PSD value. Our revised statewide CDD value is 28% higher than the current PSD value. Table 4-1 compares current and revised statewide HDD and CDD values.

Table 4-1. Statewide HDD and CDD values: current PSD vs. updates

Description	2021 CT PSD Values	Updated Values	% Difference
Statewide HDD	5,885	5,362	-8.9%
Statewide CDD	603	772	28.0%

4.2 Utility-Specific HDD and CDD Values

Compared to the current PSD HDD values, we determined utility-specific HDD values 7% and 12% lower for Eversource and UI, respectively.

Compared to the current PSD CDD values, we determined utility-specific CDD values 25% and 43% higher for Eversource and UI, respectively.

Table 4-2. Utility-specific HDD and CDD values: current PSD vs. updates

Description	2021 CT PSD Values	Updated Values	% Difference
Eversource HDD	5,885	5,473	-7.0%
UI HDD	5,885	5,165	-12.2%
Eversource CDD	603	757	25.5%
UI CDD	603	864	43.3%

4.3 Inland and Coastal HDD and CDD values

We determined inland and coastal HDD values 5% and 15% lower, respectively, as compared to the current PSD HDD value. We determined inland and coastal CDD values 23% and 37% higher, respectively, than the current PSD CDD value.

Table 4-3. Inland and coastal HDD and CDD values: current PSD vs. updates

Description	2021 CT PSD Values	Updated Values	% Difference
Inland HDD	5,885	5,578	-5.2%
Coastal HDD	5,885	5,019	-14.7%
Inland CDD	603	740	22.7%
Coastal CDD	603	823	36.5%

5 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions and recommendations of this study based on the results presented above.

Conclusion 1: The current PSD reports a single set of statewide HDD and CDD values that are based on 1978-2008 weather data of inland region only. This study presents utility-specific, statewide, and inland/coastal DD values based on 2005-2020 weather data among 10 weather stations in Connecticut, weighted by population. Statewide, the updated HDD values are 9% lower and the updated CDD values are 28% higher compared to the 2021 PSD's HDD and CDD values.

> ***Recommendation 1:*** Update the current PSD to include the inland and coastal HDD and CDD values presented in this study. Moving forward, Eversource and UI should revise program tracking systems and savings calculators to reflect the revised inland/coastal values based on project ZIP code. The inland/coastal designation simplifies the degree-day values as much as possible while acknowledging the state's two distinct climatological regions. Should it be difficult to implement separate inland and costal HDD and CDD values due to program tracking limitations, we recommended revising the PSD with utility-specific HDD and CDD values.

Conclusion 2: The discrepancy between the 2021 PSD's DD values and the revised statewide DD values arises from two main factors: 1) inclusion of other weather stations, namely coastal, in the statewide estimates; and 2) change of climate between 1978-2008 (source of current PSD estimates) and 2005-2020 (source of this study's values).

Conclusion 3: The CT PSD's Appendix Three realization rates (RRs) for residential weatherization measures are derived from the R1603 Home Energy Services-Income Eligible and Home Energy Solutions Impact Evaluation study[6]. The RRs in the R1603 study are calculated based on billing analysis of HES/HES-IE weatherization measures implemented in 2018. Upon reviewing the study, we determined that its weatherization impacts are based on a comparison between the weather-normalized, pre- and post-intervention billing periods. As the study involved weather normalization, we believe that its overlap with this research is minimal and will not result in significant potential over- or under-counting of savings. We therefore do not recommend adjusting the Appendix Three RRs to account for the revised HDD and CDD values.

Conclusion 4: The CT PSD uses an adjustment factor (F_{adj}) of 0.64 in the savings algorithm of the impacted weather-dependent measures to account for the errors inherent to the degree day method. This adjustment factor (F_{adj}) was estimated based on the empirically derived correlation between degree days (Kelvin) and correction factor presented in the 1989 ASHRAE handbook[7]. The CT PSD adjustment factor needs to be updated based on the new heating degree day values presented in this study.

> ***Recommendation 2:*** Update the current PSD to include the ASHRAE adjustment factor presented in this study.

[6] Accessed online at https://energizect.com/sites/default/files/R1603_HES%20Impact%20Evaluation_Final%20Report_10.22.19.pdf.

[7] ASHRAE. (1989). *1989 ASHRAE handbook: Fundamentals*.

6 REFERENCES

NMR Group Inc, Review of Impact Evaluation Best Practices Final Report (R91), March 30, 2016.

West Hill Energy and Computing, CT Home Energy Services – Income Eligible and Home Energy Solutions Impact Evaluation Program Years 2015-2016 Final Report (R1603), October 22, 2019.

ASHRAE. (1989). 1989 ASHRAE handbook: Fundamentals.

APPENDIX A. HDD AND CDD 65 °F VALUES FOR ALL 10 WEATHER STATIONS IN CT.

Station ID	Location	HDD 65	CDD 65
WBAN:00169	Chester Airport[1]	5,432	702
WBAN:54734	Danbury Municipal	5,685	636
WBAN:14707	Groton New London Airport	5,175	593
WBAN:14740	Hartford Bradley Intl Airport	5,636	814
WBAN:14752	Hartford Brainard Field	5,319	875
WBAN:94702	Igor I Sikorsky Memorial	4,924	888
WBAN:54788	Meriden Markham[2]	5,493	749
WBAN:14758	New Haven Tweed	4,993	841
WBAN:64707	Oxford Waterbury[2]	5,933	557
WBAN:54767	Willimantic Windham[2]	5,627	693

[1] NOAA reports weather data from 2009 to 2021 only. HDD and CDD are based on 2009 to 2021 weather data.
[2] NOAA reports weather data from 2006 to 2021 only. HDD and CDD are based on 2006 to 2021 weather data.

APPENDIX B. HDD AND CDD WEIGHTS FOR ALL 10 WEATHER STATIONS.

- Inland and Coastal Weights

Location	Inland HDD Weights	Coastal CDD Weights	Inland CDD Weights	Coastal Weights
Chester Airport	0.0%	9.3%	0.0%	9.3%
Danbury Municipal	11.4%	0.0%	11.4%	0.0%
Groton New London Airport	0.0%	12.0%	0.0%	12.0%
Hartford Bradley Intl Airport	14.1%	0.0%	14.1%	0.0%
Hartford Brainard Field	26.2%	0.0%	26.2%	0.0%
Igor I Sikorsky Memorial	0.0%	52.1%	0.0%	52.1%
Meriden Markham	19.4%	0.0%	19.4%	0.0%
New Haven Tweed	0.0%	26.6%	0.0%	26.6%
Oxford Waterbury	16.5%	0.0%	16.5%	0.0%
Willimantic Windham	12.5%	0.0%	12.5%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

- Utility-Specific Weights

Station	Eversource HDD Weights	Eversource CDD Weights	UI HDD weights	UI CDD weights
Chester Airport	0.3%	4.4%	4.1%	0.0%
Danbury Municipal	13.0%	8.4%	1.1%	0.0%
Groton New London Airport	2.5%	5.7%	0.0%	0.0%
Hartford Bradley Intl Airport	7.1%	9.4%	9.0%	0.0%
Hartford Brainard Field	6.5%	19.4%	25.9%	0.0%
Igor I Sikorsky Memorial	23.1%	11.2%	41.5%	77.4%
Meriden Markham	18.6%	12.3%	4.1%	3.7%
New Haven Tweed	0.9%	9.9%	12.3%	15.2%
Oxford Waterbury	20.5%	11.6%	0.0%	3.7%
Willimantic Windham	7.5%	7.7%	1.9%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

- Statewide Weights

Weather Station	Statewide Weights
Chester Airport	3.6%
Danbury Municipal	7.0%
Groton New London Airport	4.7%
Hartford Bradley Intl Airport	8.6%
Hartford Brainard Field	16.0%
Igor I Sikorsky Memorial	20.2%
Meriden Markham	11.9%
New Haven Tweed	10.3%
Oxford Waterbury	10.1%
Willimantic Windham	7.6%
Total	**100.0%**

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