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Article

2025

Published version

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How to cite

SCHNEIDER, Stefan et al. What type of climate correction is most accurate for monitoring the thermal demand of buildings? The case of the IDC data base (Geneva). In: Journal of physics. Conference series, 2025, vol. 3140, n° 6, p. 062032. doi: 10.1088/1742-6596/3140/6/062032

This publication URL: <https://archive-ouverte.unige.ch/unige:189755>

Publication DOI: [10.1088/1742-6596/3140/6/062032](https://doi.org/10.1088/1742-6596/3140/6/062032)

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What type of climate correction is most accurate for monitoring the thermal demand of buildings? The case of the IDC data base (Geneva)

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Abstract. In order to track the evolution of building heat demand in relation with building retrofit and other saving measures, a specific challenge consists in applying of a proper climate correction method. In this paper, we compare the Heating Degree Days (HDD) and Accumulated Temperature Differences (ATD), as applied to actual energy metering of around 18,000 buildings, over more than a decade. We conclude that for the current building stock, there is little difference between the HDD and the ATD methods. However, as most buildings are expected to meet high energy standards in future, switching from HDD to ATD with an appropriate space heating cut-off temperature could be of interest. Finally, using a specific example at territorial level, we demonstrate that the use of daily energy demand data can facilitate the development of a highly effective climate correction model.

1. Introduction

For more than a decade, the Canton of Geneva has been monitoring the final energy demand for production of space heating and domestic hot water of its building stock. Such is done by way of an annual heat demand index IDC [1], which is calculated individually for 18,000 buildings, mostly multi-family, representing 72% of the heat demand of the entire building stock. To make the evolution of this index comparable between subsequent years, a climate correction based on Heating Degree Days (*HDD*) is applied. However, the latest version of the national SIA 380/1 standard [2] recommends switching from the *HDD* method to the *ATD* method (Accumulated Temperature Differences). In this study we compare the effectiveness of these correction methods, when applied to large datasets of actual energy consumption data. The first comparison concerns annual consumption data given by the IDC database, while the second is based on a large set monthly gas bills. Finally, a more sophisticated climate correction model, which requires daily consumption data, offers an interesting perspective when such data is available.

Note that a previous study [3] made similar comparisons, however based on simulated energy demand.



2. Climate correction methods

This first section introduces the climate correction methods that will be compared. These methods aim to eliminate as much as possible the effects of climate, ensuring that the demand for heating is comparable between subsequent years.

2.1. Climate correction based on HDD

$HDD(T_{NH}, T_{Ind})$ depends on two base temperatures T_{NH} (space heating cut-off) and T_{Ind} (indoor). It is calculated for daily average outdoor temperatures T using:

$$HDD(T_{NH}, T_{Ind}) = \sum_{T \leq T_{NH}} (T_{Ind} - T) \quad (1)$$

T is either the real outdoor temperature to calculate $HDD_{Real}(T_{NH}, T_{Ind})$ or the one of a reference climate to calculate $HDD_{Ref}(T_{NH}, T_{Ind})$, which allows to define following climate correction factor:

$$F_{Corr_HDD} = \frac{HDD_{Ref}(T_{NH}, T_{Ind})}{HDD_{Real}(T_{NH}, T_{Ind})} \quad (2)$$

2.2. Climate correction based on ATD

Unlike before, $ATD(T_{NH})$ depends only on T_{NH} :

$$ATD(T_{NH}) = \sum_{T \leq T_{NH}} (T_{NH} - T) \quad (3)$$

As before, T can be either the real outdoor temperature or temperatures of a reference climate, yielding following climate correction factor

$$F_{Corr_ATD} = \frac{ATD_{Ref}(T_{NH})}{ATD_{Real}(T_{NH})} \quad (4)$$

Note: in preceding calculations, data for the reference climate is provided by the SIA 2028 standard [4], while data for the real climate is provided by MeteoSwiss via IDAWEB [5].

2.3. Climate corrected heating index (IDC)

For both corrections, the climate-corrected IDC heating index (kWh/m^2) allows to estimate what the building's energy demand would be in a reference climate. It is calculated by multiplying the actual energy demand for space-heating E_{sh} by the corresponding correction factor, while keeping the domestic hot water E_{dhw} unchanged. Finally, the climate corrected energy demand is divided by the heated surface A_E , making buildings of different size comparable :

$$IDC = \frac{(f_{corr} \cdot E_{sh} + E_{dhw})}{A_E} \quad (5)$$

Note: generally, in absence of separated meters for E_{sh} and E_{dhw} , the latter is given by a standard value, which is deducted from the global energy meter to yield E_{sh} [1].

3. Results

3.1. Comparison of HDD and ATD methods on yearly energy consumption

In a first step, we compute the climate corrected heat indices for 59,539 annual energy demands of the IDC database (covering the period from 2010 to 2022), both with the $HDD(16,20)$ and the $ATD(17)$ method. Figure 1 shows the ratio of these two values, plotted against the $HDD(16,20)$.

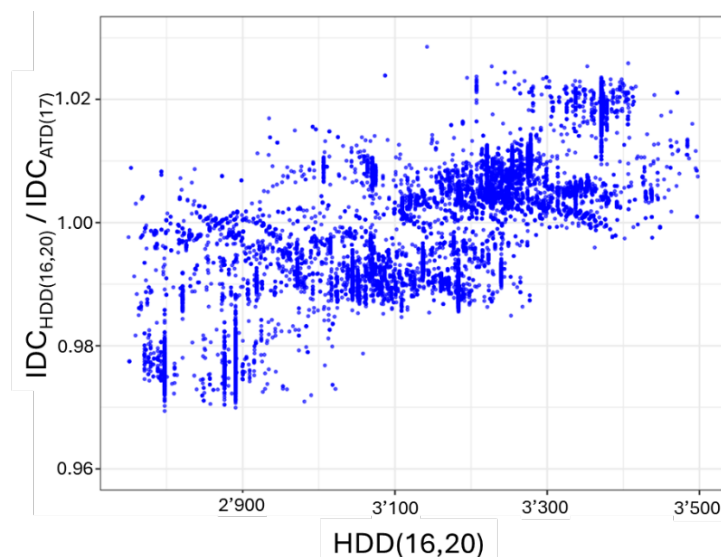


Figure 1. Ratio of climate corrected demand (y-axis) depending on HDD (x-axis).

For milder winters (values on the left), the IDC calculated using $HDD(16,20)$ are lower than those calculated using $ATD(17)$. This suggests that, with global warming, the IDC based on $HDD(16,20)$ will decrease faster than the IDC based on $ATD(17)$. However, the effect is marginal, of the order of 1 to 2%. It does further not allow to conclude that one method is more effective than the other. The next section will provide further information to help answer this question.

3.2. Comparison of HDD and ATD methods on monthly energy consumption

As a complementary analysis, we analyse 305,788 gas bills from the local utility (SIG), which were filtered for meeting of the following five criteria: (i) a number of consumption days between 10 and 40; (ii) at least 15 invoices per building; (iii) the building has one single boiler and (iv) the building is a multi-family residential building; (v) the end of the billing period is between January 2020 and December 2021 (before outbreak of war in Ukraine, which resulted in reduced gas consumption due to the implementation of efficiency measures). Ultimately, 13,702 invoices were retained, covering a total of 683 buildings.

Using the same method as in [7], we analyse for each building the relationship between the fraction of yearly demand $\%E_i$ covered by bill no i , and the related HDD_i or ATD_i over the same period. We assume that the better the climate correction, the closer the points will be aligned to the least-squares linear fit LM_i (computed for HDD_i or ATD_i). Hence, we assess the quality of the climate correction by way of the mean square deviation MSD :

$$MSD = \sqrt{\sum(LM_i - \%E_i)^2} / Nb \text{ bills} \quad (6)$$

Figure 2 illustrates the various fits and corresponding MSD values for two buildings, where $HDD(16,20)$ gives the best fit for building 1 and $ATD(13)$ gives the best fit for building 2 (see MSD values on the top of the figure).

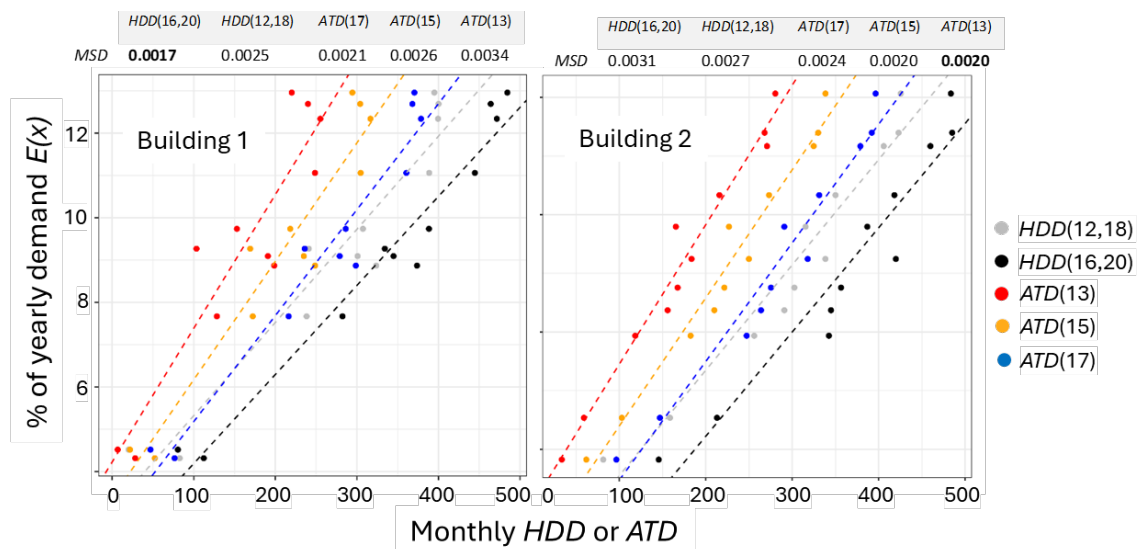


Figure 2. Example of the fraction of the yearly demand for two buildings depending on HDD or ATD , with indication of the mean square deviation MSD (top).

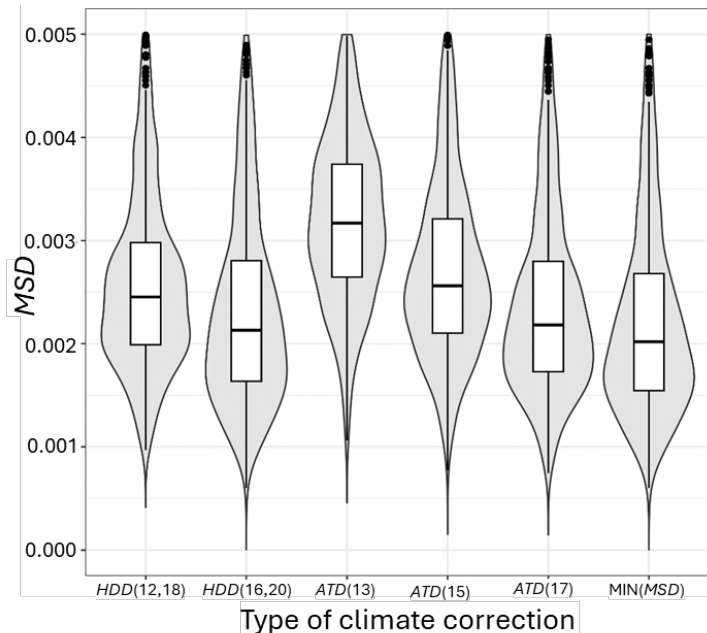


Figure 3. Distribution of MSD values for 683 multi-family residential buildings for different climate correction methods.

Figure 3 shows the distribution of MSD values over the 683 buildings, for the various climate corrections. In addition, the $MIN(MSD)$ distribution corresponds to selecting, for each building, the method that produces the smallest value. Overall, the $HDD(16, 20)$ and $ATD(17)$ methods perform

best, producing values close to those obtained by an 'optimal' selection at building level, as represented by $MIN(MSD)$.

3.3. Refined climate correction for daily energy consumption

Following the outbreak of war in Ukraine, important incentives to reduce gas consumption were introduced during the winter 2022-2023. To estimate these savings, a refined climate correction method was applied to the daily overall gas consumption of the Canton of Geneva [8]. The method can be summarized as follows. For a given year, the method first estimates the regression parameters a_0 to a_8 of the regression model given by equation (7), which bases on a variety of climate data such as: external temperature (T), external temperature of the previous day ($T(t - 1d)$), global solar radiation (GS), wind speed (VS) and rain amount (QR). $NW(t)$ indicates whether the day is a working day (0) or a non-working day (1). T_{NH} is the space heating cut-off temperature, which is set to 17 °C, as estimated by way of a simple energy signature.

$$Q_{gas}(t) = \begin{cases} \text{if } T(t) \geq T_{NH}: a_0 + a_1(T_{NH} - T(t)) - a_2 NW(t) \\ \text{if } T(t) < T_{NH}: a_0 + a_3(T_{NH} - T(t)) + a_4(T_{NH} - T(t - 1d)) - a_5 VS(t) \\ -a_6 GS(t) - a_7 QR(t) - a_8 NW(t) \end{cases} \quad (7)$$

The climate-corrected consumption is obtained by applying equation (7) and the previously estimated parameters to a reference climate.

Figure 4 shows the results of this analysis over a 5 year period, for which the first year (2018 = Sep18 – Aug19) is defined as the reference year. The refined daily correction method “Daily CC” is compared to the various *HDD* and *ATD* methods, as well as to the non-corrected demand “No CC”.

During the first four years, the Daily CC method yields a quite stable consumption, with a slight increase due to the replacement of oil boilers with gas boilers and an increase in the heated surface area. The sharp decrease in 2022 (Sep22 – Aug23) reflects the savings achieved by the energy efficiency measures implemented after the outbreak of war in Ukraine. The *ATD*(17) and *HDD*(16,20) methods are the second and third best methods, confirming the previous results.

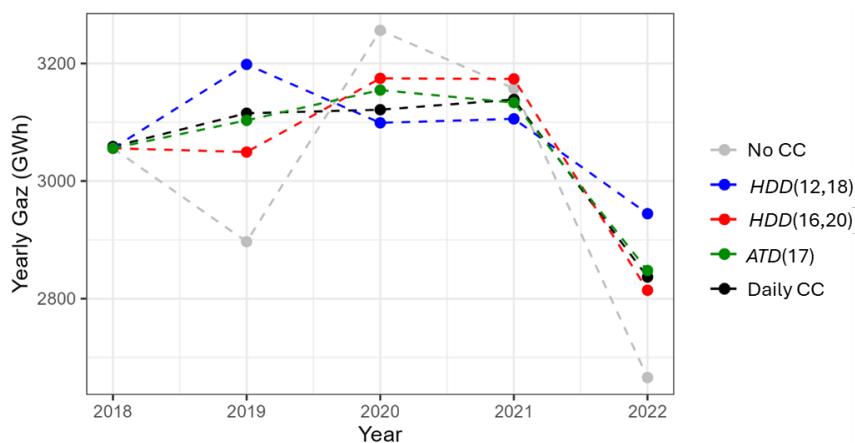


Figure 4. Geneva’s gas consumption normalized to the 2018 climate for several climate correction methods. The annual demand of a given year ranges from September to August of the following year.

4. Conclusions

A comparison of the *HDD*(16,20) and *ATD*(17) methods based on data from over 59,000 annual energy demands reveals that, during milder winters, the *HDD*(16,20) method applies a higher correction factor to energy demand than the *ATD*(17) method. Consequently, the climate-adjusted energy demand is lower. Statistically, the difference is however relatively small, at around 1%. Moreover, this observation does not allow us to conclude which method is more accurate.

A complementary analysis of 13,702 monthly gas bills covering 683 multi-family residential buildings reveals that the *HDD*(16,20) and *ATD*(17) corrections are more efficient than the other ones studied.

Finally, we demonstrate that a refined model based on daily energy demand data can be used to develop a highly accurate climate correction method, at least at overall territorial level. This method is particularly useful for monitoring of energy-saving measures. The main challenges of using such a method at building level would be obtaining and processing the large amounts of data required for each building and establishing of a reference climate.

Acknowledgements

The authors are thankful the following entity, that funded this research: *Office cantonal de l'énergie de Genève* (OCEN). We also thank the *Services industriels de Genève* (SIG) for providing monthly gas billing data.

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