Energy and Buildings 49 (2012) 109–118

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Evaluation of weather datasets for building energy simulation

Mahabir Bhandari*, Som Shrestha, Joshua New

Oak Ridge National Laboratory, Oak Ridge, TN, USA

ARTICLE INFO

Article history:
Received 8 November 2011
Received in revised form 19 January 2012
Accepted 28 January 2012

Keywords:
Weather data
Climate
Building energy simulation
EnergyPlus

ABSTRACT

In recent years, calibrated energy modeling of residential and commercial buildings has gained importance in a retrofit-dominated market. Accurate weather data play an important role in this calibration process and projected energy savings. It would be ideal to measure weather data at the building location to capture relevant microclimate variation but this is generally considered cost-prohibitive. There are data sources publicly available with high temporal sampling rates but at relatively poor geospatial sampling locations. To overcome this limitation, there are a growing number of service providers that claim to provide real time and historical weather data necessary for building modeling at 15–40 km^2 grid across the globe; common variables such as temperature and precipitation have been constructed on ∼1 km^2 grids [1]. Unfortunately, there is limited documentation from 3rd-party sources attesting to the accuracy of this data. This paper compares provided weather characteristics with data collected from a weather station inaccessible to the service providers. Monthly average dry bulb temperature; relative humidity; direct normal, diffuse and global solar radiation; wind speed and wind direction are statistically compared. Moreover, we ascertain the relative contribution of each weather variable and its impact on building loads. Annual simulations are performed for three different building types, including a closely monitored and automated energy efficient research building. The comparison shows that the difference for an individual variable can be as high as 90%. In addition, annual building energy consumption can vary by ±7% while monthly building loads can vary by ±40% as a function of the provided location's weather data.

1. Introduction

Building energy simulation is increasingly necessary for accurately quantifying potential energy savings measures in compliance with building code trade-offs and new legislation. For example, California has passed AB 758 and AB1103 that require energy modeling whenever commercial properties change hands. This dramatically increases the need for certified auditors skilled in the use of energy assessment tools that can identify cost-effective energy efficiency improvements, prioritize those improvements, and provide a credible estimate of payback period or cost-effectiveness for each one. Enhanced automation of current calibration methodologies is needed to reduce the manual costs necessary for fulfilling such requirements. Accurate weather data for the microclimate surrounding a given building during the time that data was collected is necessary for accurate calibration.

There are three main classes of weather data with traditional use cases for each: "typical" weather data (representative of some location over an arbitrary period of time) often used for design and performance conditions over the life of a building, "actual" weather data (at a specific location for a specific period of time) used for simulation calibration to energy bills, and "future" weather data used for adaptive control of a building. There are a multitude of representative weather datasets for each class, among the most popular of which include: the Typical Meteorological Year (TMY2 [2], TMY3 [3]), International Weather for Energy Calculation (IWEC) [4] datasets, the world's largest active archive of weather data at the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) including the currently 12,000-location Integrated Surface Hourly (ISH) dataset for actual weather measurements, and sources provided by NOAA's National Weather Service [5] for future weather data. However, the best dataset for an individual will depend on the purpose, location, and simulation engine being used. The interested reader can find many weather datasets for use with EnergyPlus at [6]. In this paper, analysis is performed solely for actual weather data in order to facilitate increased automation of simulation calibration and allow for a more direct comparison between measured data and vendor-provided data.

* Corresponding author at: Oak Ridge National Laboratory, 1 Bethel Valley Rd, Oak Ridge, TN, USA. Tel.: +1 865 574 0989; fax: +1 865 5743851.
E-mail addresses: bhandarims@ornl.gov (M. Bhandari), shresthass@ornl.gov (S. Shrestha), newjr@ornl.gov (J. New).

0378-7788/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.enbuild.2012.01.033

2. Approach

2.1. Previous work

The Building Energy Software Tools Directory [7] currently lists more than 400 software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings with approximately 120 tools just for whole building energy simulations. These tools are becoming increasingly sophisticated and include the capability of representing the building and its systems in great detail, in order to realistically capture the relevant properties of the building system. However, the uncertainties of various input parameters for a model generally increase with the breadth and depth of possible inputs, leading to unrealistic simulation results. Weather data is one of the important sets of input parameters required to adequately simulate the thermal behavior of buildings and can have a significant impact on the output of these simulation tools. Weather data can influence the building performance in several ways; for example, dry bulb temperature and solar radiation influence the heating and cooling loads while relative humidly impacts the latent load of the building and sizing of HVAC equipment. There are also strong correlations between weather variables; with an increase in global horizontal irradiation (GHI), dry bulb temperature (DBT) would generally increase, while the relative humidity (RH) tends to decrease [8]. That study suggests that simply comparing one parameter between two weather datasets may not give a complete picture of the influence this variation may have in overall energy consumption.

Huang and Crawley showed the variation inherent in actual weather data and how it influenced the simulation results [9]. They used six typical weather datasets for this 1996 study and performed the simulations for a typical office building using DOE2.1E hourly simulation program [10] for five different US locations. They concluded that the average variation in annual energy consumption due to weather variation is ±5%. Lama et al. [11] analyzed the measured long-term hourly weather data for five Chinese cities with different climates with the intent that researchers and designers could use the distribution plots of weather data and consumption profiles for their building design and analysis. Seo et al. [12] studied the impact of typical weather year selection approaches on energy analysis for a 3-story office building using the DOE-2 simulation program. The results of this study showed a maximum 5% difference between the simulation results obtained using any typical weather datasets (TMY, IWEC, and TMY2) and those obtained by averaging the results for 30 years for 10 US climates.

Recently, several researchers have investigated the impact of climate change on energy consumption of buildings. Many studies have begun to incorporate future models of weather based on climate change to develop typical weather data that, it is anticipated, more accurately represents the weather to be seen in the lifespan of new buildings via the impacts of climate change [13–15]. Chan [16] developed a set of typical weather files based on climate change and analyzed their impact on a typical office building and a residential apartment using EnergyPlus. His study indicated that there would be a substantial increase in the energy consumption of air-conditioning systems in those two types of buildings in Hong Kong, ranging from 2.6% to 14.3% for office buildings and from 3.7% to 24% for a residential apartment. Radhi [17] investigated the issue of localized climate variability between the pre-1991 climate and the post-1991 climate of Bahrain, believed to be induced by oil fires and urban heat island effects from heavy reclamation efforts, and evaluated its impact on the performance of weather data used in building simulation. He used these two sets of weather data in the context of a low-rise and high-rise commercial building to compare the predicted and measured energy consumption. The study concluded that the traditional pre-1991 weather files tended to underestimate the electricity consumption by 14.5% and misrepresented the cooling load by 5.9–8.9%, whereas, the more recent weather data underestimated actual consumption by 1.4%.

The aforementioned studies quantify the impact weather data has on the thermal performance of a building. However, no studies could be found comparing the impact of different weather files from many current data sources and web-services, several of which have come online only recently. While the building simulation community traditionally utilizes "typical" weather data, the objective of this work is to compare "actual" weather data with the measured "ground truth" dataset. Moreover, a difference of weather data for a specific variable does not necessarily translate into a meaningful impact on building performance, so we also compare the impact of the various weather data in the context of annual building energy simulations.

2.2. Study design

The aim of this paper is to investigate the impact of available weather data of present and past actual conditions on the thermal performance of buildings. The data will be presented in terms of heating and cooling loads so that the results are not overshadowed by the efficiency and performance of HVAC systems. The minimum weather data parameters necessary for whole building simulations accuracy are: dry bulb temperature; wet bulb temperature and/or relative humidity, global, direct normal and diffuse solar radiation (only two variables are required to represent solar radiation); wind speed and wind direction (for natural ventilation and infiltration). Some providers claim to have full set of data for all the locations around the world with a geospatial resolution of a 15–40 km^2 grid. Some weather vendors use data from the nearest available weather sensor (typically NOAA weather data at airports), some use statistics to interpolate from several nearby sensors to the target location, and others use nearby sensor data to seed a gridded mesoscale climate simulation model to provide simulated weather at the target location. Each technique has its strengths and weaknesses and there is little consensus on which technique is most accurate.

Sources of historical weather data were identified and providers were contacted to procure these datasets. Fourteen weather data vendors were identified that provided either full or partial sets of weather data necessary for whole building energy simulations; however, only two providers were chosen for this study. Other providers either did not feel comfortable with participating in the study or did not have a complete set of data available for the study location (Oak Ridge, TN, USA; Latitude: 35°57′N, Longitude: 84°17′W, elevation: 334 m) for the 2010 calendar year. The providers' data will be denoted as Set 1 and Set 2 and on-site measured data as Meas, for a total of three datasets (Table 1).

A brief description of weather station at study locations is as follows:

Weather station located in Oak Ridge was used to collect weather data for the comparisons. Table 2 shows the sensors used at the weather station and their accuracy. Solar irradiation data was taken from the weather station located at ORNL campus, which is maintained by the National Renewable Energy Laboratory's (NREL) Measurement and Instrumentation Data Center (MIDC). While global horizontal and diffuse horizontal irradiations were measured, the direct normal irradiation was calculated from global and diffuse measurements.

For quality assurance, the measured field data was compared to predictions of the ASHRAE clear sky model [18]. Fig. 1 compares the field measured vs. ASHRAE clear sky model predicted global horizontal radiation and direct normal radiation on a clear sky day. The measured total direct normal was 1.3% higher and global horizontal was 6.1% lower compared to the model predicted values for the day.