COLUMN ENGINEER'S NOTEBOOK

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Weather Data Analysis

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Presenting graphical representations of the weather data for project locations has become a staple of energy-efficiency practice, both by architects and engineers. Practitioners seem to vie for ever more colorful and dramatic renderings of this data. Unfortunately, too often, these presentations merely render numerical data without providing useful information that can lead directly to conclusions concerning the directions that design efforts should take. The climate data analysis does not answer the question: "So what?" This column will explore some ways by which the initial climate data analysis, exclusive of any particular data about the building design, can provide useful information for the development of both the architectural and mechanical systems of the building.

Introduction

Climate responsive design is now the watchword of the sustainable design community. To achieve that goal, designers must understand the climate for which they are designing, and to achieve that level of understanding, must process raw data concerning temperature, humidity ratio and solar angles into a format that conveys understandable information. Too often, presentation of raw climate data in a graphical format is followed immediately by energy modeling efforts, often resulting in wasted time and effort studying issues that could have been resolved by a more sophisticated climate analysis. Examples of simple representation of climate data are shown in *Figure 1*. These examples represent monthly averages of single parameters by month and by hour of the day, but this information offers little help to the potential building designer.

Some of the issues for which sophisticated climate analysis can give insight include:

- Comfort potential of exterior spaces;
- Availability of different forms of free cooling;
- Effectiveness of solar shading devices;
- Insight into most effective HVAC system for that climate; and
- Effectiveness of HVAC condensate collection.

While some of these issues, specifically comfort potential for exterior spaces, are accessible from commercially available climate data rendering platforms, most are not. Custom spreadsheets, however, can manipulate the climate data to provide insights to these other issues.

Availability of Climate Data

Climate data for most major locations throughout the world are available in a number of formats. The data are available as monthly and yearly averages, as bin data, and as hourly data for a number of parameters, including:

- Dry-bulb temperature;
- Dew-point temperature;
- Barometric pressure;
- Cloud cover;
- Precipitation; and
- Wind speed.

Other parameters that are either a measure of the moisture content of the air or a function of the combined dry-bulb temperature and moisture content are also available or are easily calculable from the parameters above. These include:

- Humidity ratio;
- Wet-bulb temperature; and

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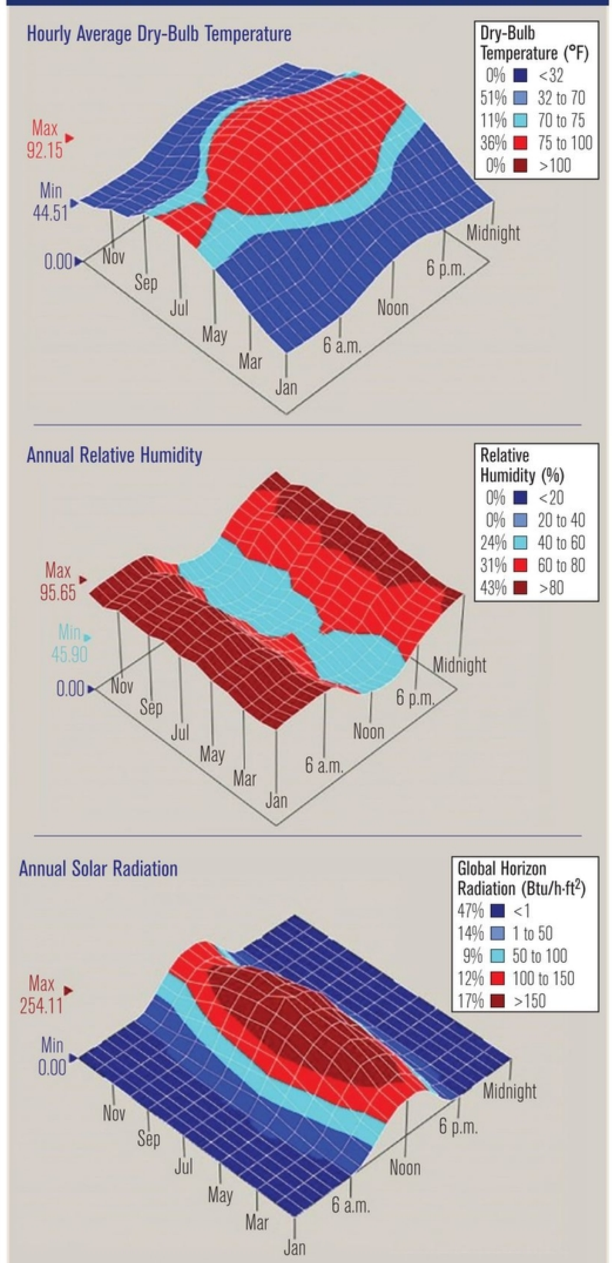
- Relative humidity.

While averages and bin data have their uses, each format has certain limitations. Averages, whether monthly or annually, typically do not show the range of variation of the specific parameter, nor the relationship between multiple parameters. Bin data captures the range of variation of a specific parameter, but, typically shows, at most, a minimal correlation between parameters (e.g., mean wet-bulb temperature for a specific dry-bulb temperature bin). For most advanced weather analytic studies, hourly data is the best primary resource as it captures both simultaneous occurrences of multiple parameters along with time of day correlation. A body of hourly observations of simultaneous weather parameter observations can be processed to provide time of day related analyses, i.e., monthly heating degree hours during the office occupancy period. The most common form of portraying the simultaneous occurrences of dry-bulb temperature and moisture content of the air is hourly frequency bin diagram portrayed on a psychrometric chart, as shown in *Figure 2* for New York City, with comfort zones shown for two levels of clothing in still air and for airflow across the body at 236 fpm (1.2 m/s) velocity. This graphic gives insight into the feasibility of natural ventilation in that location. Although the comfort zone is determined, in ASHRAE Standard 55-2016,[1] by the operative temperature, a function of both the air temperature and mean radiant temperature, a good presumption would be that, barring excessive solar irradiation, interior surface temperatures are likely to approximate air temperature when conditioning is by natural ventilation.

Another useful climate graphic portrays diurnal temperature variation, in this case for a California location. The graphic demonstrates that in all months, the diurnal swing for almost all days traverses the comfort zone (in this case, determined by the software package and not necessarily related to ASHRAE Standard 55-2016[1]). Portrayal of weather data in this format strongly suggests that a thermally massive building with adequate controlled outdoor ventilation could maintain comfort without recourse to refrigerated cooling.

FIGURE 1 Simple representation of climate data (image courtesy WSP Group).



Psychrometric Climate Analysis

Packages of psychrometric functions that can be embedded in the most common spreadsheet platforms are available from several vendors. These packages are extremely valuable for processing annual weather data consisting of 8,760 sets of hourly weather observations of multiple weather parameters. While the typical Typical Meteorological Year (TMY) weather data format includes all common parameters that describe moisture content related metrics, dry-bulb, wet-bulb, dew-point, humidity ratio, vapor pressure and enthalpy, some hourly data sources are not this complete, and will require processing at least two of the non-parallel psychrometric parameters to obtain those not included in the original data set. Embedded functions allow this processing to be performed easily for all 8,760 instances.

A particularly valuable study for pre-schematic design involves determination of the availability of various forms of free-cooling in a particular climate. For the chart shown in *Figure 3,* a spreadsheet was prepared that evaluated each hour with respect to whether each form of free cooling was available in that hour, based upon rules for that form of free cooling. The data set from which this was drawn was limited to office occupancy (7 a.m. to 7 p.m.). For example, free cooling from air-side economizer was evaluated based upon whether the outdoor air dry-bulb temperature was 53°F (11.7°C) or below, without supply air reset,and for 58°F (11.7°C), while part cooling with reset was determined by whether or not the outdoor air enthalpy was less than 28 Btu/lb (66.1 kJ/kg). Full cooling for waterside economizer was based upon whether or not the outdoor air wet-bulb temperature was 39°F (3.9°C) or below. Availability of natural ventilation using operable windows tested whether the outdoor ambient air was cool enough to provide cooling, warm enough to avoid drafts and dry enough to overcome internal latent gains in the building according to the criteria established by CIBSE.[2]

This type of analysis can have significant influence on selection of HVAC systems. High availability of airside

FIGURE 2 Ambient air temperature in New York City compared with ASHRAE comfort zones.

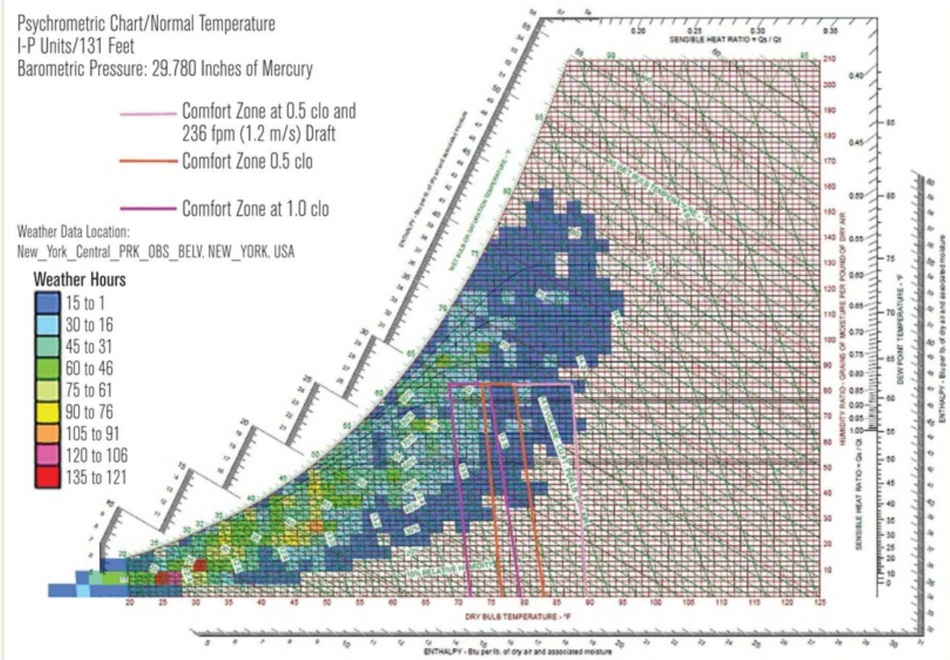
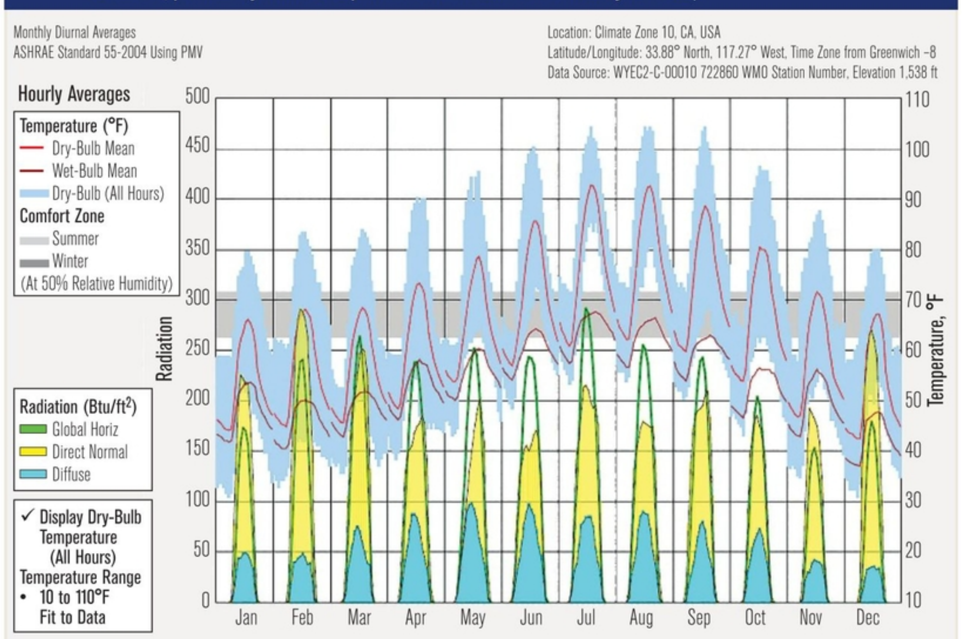


FIGURE 3 Monthly diurnal temperature average and solar radiation data for a California location. (Image produced using Climate Consultant, produced by the UCLA Department of Architecture and funded by U.S. DOE.)

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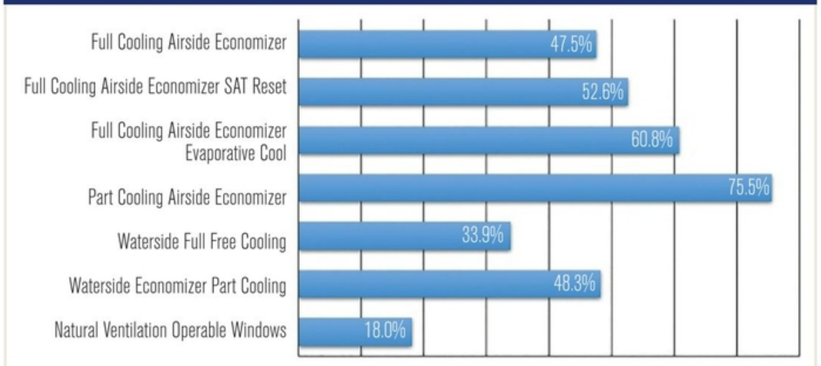
economizer and low availability of waterside economizer, for example, San Francisco, would suggest an all-air system, with central air-handling units and outdoor air access, as opposed to a water or refrigerant fan coil system with dedicated outdoor air system sized only for the airflow ventilation rate.

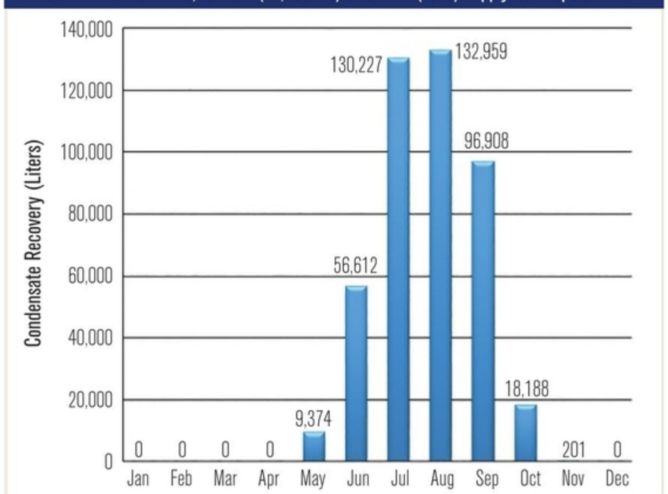
FIGURE 4 Availability of free cooling for office occupancy schedule in New York City (percent of hours).



HVAC Condensate Recovery

Another issue that can be assessed prior to building design is the feasibility of harvest condensate from a DOAS system. *Figure 5* was created in a spreadsheet using a TMY3 weather file for New York City. Inputs consisted only of a ventilation flow rate, ventilation schedule, supply air temperature (it is presumed that supply air temperature will be constant whenever outdoor air requires dehumidification), and latent efficiency of the energy recovery device.

FIGURE 5 Monthly recovered condensate from a DOAS in New York City, assuming office ventilation schedule and 106,120 cfm (50,083 L/s) and 50°F (10°C) supply air temperature.



Solar Shading Effectiveness

Renderings of solar data in a location often include a sun angle diagram as shown in *Figure 6*. These diagrams are readily available from a variety of sources, but require significant processing to yield any information concerning the design.

Figure 7, on the other hand, shows the results of a processing an entire year of sun angle data to determine the effectiveness of a simple overhang sunshade for windows on the south, east and west sides of the building, compared with no overhangs. This diagram was generated by calculating, on an hourly basis, for each month of the year, the depth of the shadow on a window of a certain height immediately below the overhang. The percentage of the window above the shadow line was then mapped onto a gray scale, to show shading percentage pattern over the entire year. This diagram shows that, near the middle of the day, in the summer months, when cooling loads are likely to be highest, the horizontal overhang does provide some benefit for shading the window. More comprehensive studies using this tool have demonstrated that the impact of the horizontal sunshade on the east and west is more profound at lower latitudes.

FIGURE 6 Sun angle chart for 40 degree north latitude.

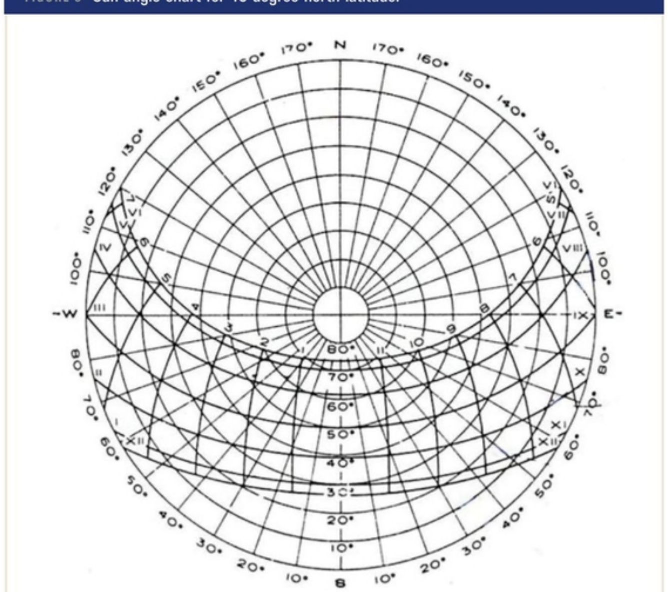
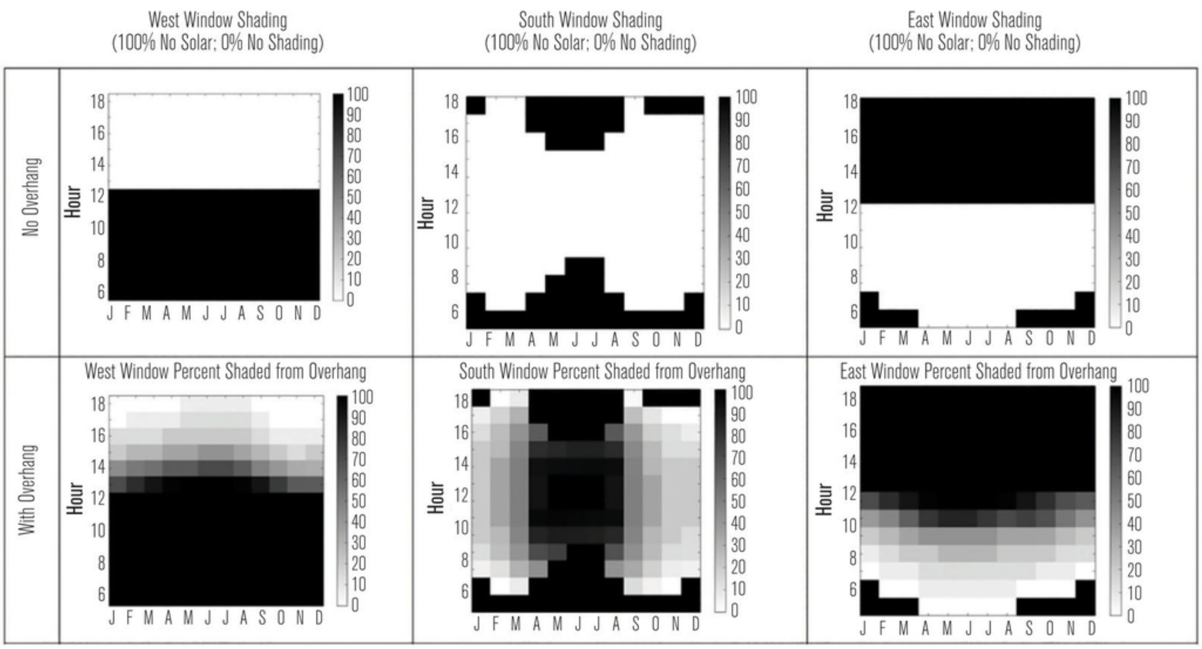


FIGURE 7 Shading effectiveness diagram for 2 ft (0.6 m) horizontal overhang for Houston. (29.7° nsorth latitude). (Image courtesy WSP Group)



Conclusion

Climate analyses are a very common component of the pre-design phase of most projects that aspire to energy efficiency goals. These studies designed to facilitate climate responsive design, enabling higher levels of energy efficiency. Many of the available examples of climate analysis, however, are merely colorful renderings of the raw climate data. Actual insight into appropriate energy-efficiency strategies typically is delayed until actual building energy modeling commences. The examples in this article demonstrate that significant insights can be gained from processing the raw climate data, using standard spreadsheets, that accept climate data input for specific locations, and generate information directly relevant to the building project. Using this data to generate these analyses with a standard spreadsheet facilitates more generic conclusions about the impact of local climate on strategies for the building and eliminates the need for generic energy modeling efforts that are more time consuming.

References

1. ASHRAE Standard 55-2016, *Thermal Environmental Conditions for Human Occupancy*.

2. CIBSE. 2005. “Application manual AM10: natural ventilation in non-domestic buildings.” London: Chartered Institution of Building Services Engineers. ■