INTRODUCTION

While the reduction of heating energy remains an important goal in China, there is now a pressing need to address cooling energy. The use of air-conditioning is burgeoning as occupants increasingly can afford to purchase and operate cooling equipment. In Beijing, for example, formal surveys as well as first-hand experience of the authors and Chinese colleagues suggest that while many people use air-conditioning, others who are unaccustomed to it or are more careful about shading and ventilating their units are able to remain thermally comfortable without it. This research strengthens an understanding of how housing can be designed and operated to provide a viable (comfortable and affordable) alternative to air-conditioning equipment.

This chapter first discusses thermal comfort and then presents findings from three technical studies for three different cities and climates. The first study (Carrilho da Graça et al 2002) examined wind-driven ventilation in Beijing and Shanghai dwellings without mechanical ventilation or cooling. Using widely applied thermal-comfort standards and appropriate wind speeds, this study showed that the number of uncomfortably warm hours could be reduced substantially in Beijing and, to a lesser extent, in Shanghai. The second study (Norford et al 1999) focused on thermal comfort in Beijing housing, complementing the first study by including mechanical
ventilation to guarantee airflow even when neighboring buildings screened a given dwelling from winds that might otherwise provide cooling. The second study also examined the impact of increasing the allowable maximum temperature, as has been found appropriate by recent work on thermal comfort. It was found that thermally comfortable indoor conditions without air-conditioning could be maintained throughout a typical summer in the limit of eliminating solar gain and internal loads. This limit can be approached via careful shading and choice of building materials and appliances. The third study concerned an energy-efficient housing development in Shenzhen, with the goal of providing guidelines to the developers about the site and the construction of the dwellings. To aid in the initial selection of low-energy buildings, a simple-to-use numerical program is included in the CD at the end of this book. This will allow a first indication of the value of good building design, construction quality, and proper material selection on overall energy use.

Thermal Comfort

Understanding what range of temperatures is considered by building occupants to be comfortable is an important first step in predicting building-energy consumption. This will help identify how such opportunities as using natural ventilation in lieu of vapor-compression cooling affect energy savings and the comfort of the occupants.

The international thermal-comfort standard identifies 26°C as the upper bound of the thermal-comfort region under humid conditions (ASHRAE 2001, ISO 1994). This upper bound increases with airspeed at the skin. For a relative humidity of 50 percent, light clothing, and sedentary building occupants, Fanger's predicted-mean-vote (PMV) method for estimating thermal comfort predicts a thermally neutral temperature of 26°C for an air speed of 0.2 m/s and 28°C when the air speed is 1.5 m/s. Lechner associated an air speed of 1 m/s with an equivalent temperature reduction of 3.3°K (Lechner 2001).

While the thermal-comfort model embodied in the standard accounts for air speed, it is based on laboratory tests, not field measurements in the workplace or home, and has its origins in Western countries. Many have observed that the ISO thermal comfort zone simply does not apply in all regions of the world (Khedari et al 2000). It is not a matter of doing with less cooling and less comfort in response to economic pressures, but rather of establishing conditions that people prefer. A study of adaptive thermal comfort in Thailand showed acceptable indoor temperatures of 28°C for air-conditioned offices and 31°C for naturally ventilated offices (Busch 1992). A separate study in Bangkok established an upper limit to thermal comfort of 31.5°C (Jitkhajornwanich et al 1998), 5.5°K beyond the upper boundary presented by ASHRAE. Motivated by a desire to reduce air-conditioning loads in Thailand without sacrificing comfort, Khedari recorded thermal sensation votes of college students cooled with desktop fans. The thermally neutral temperature was 30.6°C when the air speed was 1 m/s and the relative humidity was between 50 and 60 percent and increased to 33.5°C under more humid conditions (50–80 percent relative humidity) when the air speed was increased to 2 m/s. Kwok (1998), working in Hawaii, found that occupants of naturally ventilated classrooms were comfortable in conditions beyond ASHRAE specifications and noted the potential impact of such results in a state that is highly dependent on imported fuel. Oseland (1998) found that occupants of naturally ventilated offices in England had a wider thermal-comfort range than did those in air-conditioned offices.

These and other studies have led to proposals for adaptive thermal-comfort models and standards in which an indoor comfort temperature is related to the outdoor