Turning up the thermostat in tropics shows promise for energy and comfort

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The map above shows Singapore and outline of Singapore and its surrounding islands and waterways. Credit: University of California - Berkeley

Slightly raising indoor temperatures and equipping office workers with smart fans saves significantly on overall office building energy costs while maintaining employee comfort, according to new research that could guide the design and operation of new and existing office buildings in the world's tropical regions.

In the latest issue of *Indoor Air*, an interdisciplinary team of researchers from the UC Berkeley, Nanyang Technological University in Singapore and Stanford University lays out the results of experiments conducted in the tropical city-state of Singapore. Some 50 percent of electricity in Singapore is consumed by commercial and residential buildings, mainly to supply air conditioning for occupant comfort and to dehumidify air conditioned spaces.

Key findings include:

- Thermal comfort, perceived air quality and symptoms of sick building syndrome are reported to be equal or better at 26° Celsius and at 29°C, rather than at the common "set point" of 23°C, if a personally controlled fan is used.
- The best cognitive performance, as indicated by task speed, was recorded at 26°C; at 29°C, the availability of an occupant-controlled fan partially mitigated the negative effect of the elevated temperature. The typical Singaporean indoor air temperature set point of 23°C yielded the lowest cognitive performance.

In the United States, about 75 percent of electricity is used in buildings. Meanwhile, in the U.S. and worldwide, air conditioning accounts for 40 percent of total energy use and relative greenhouse gas emissions.

"In 2050, most of the world population will live in the tropics, and the use of air conditioning is already exploding in tropical countries. Forecasts for an even hotter, more densely populated and wealthier planet just add to the significance of our research," said Stefano Schiavon, a UC Berkeley assistant architecture professor in sustainability, energy and environment and a researcher with the College of Environmental Design's Center for the Built Environment.

A principal investigator on the Singapore research, Schiavon worked with fellow members of Singapore Berkeley Building Efficiency and Sustainability in the Tropics (SinBerBEST), a wide-ranging group of researchers from UC Berkeley, Nanyang Technological University (NTU) and the National University of Singapore (NUS). It is a program of the Berkeley Education Alliance for Research in Singapore (BEARS). For the cognitive tests, Schiavon collaborated with a doctoral student from Stanford.

Air conditioning is needed to provide comfortable and productive working and sleeping environments, but its impact on the environment and the electrical grid is large, the team said.

Lee Kuan Yew, Singapore's prime minister from 1959 to 1990, called air conditioning "a most important invention," without which work on the island city-state would be limited to cool early morning hours or dusk.

"The first thing I did upon becoming prime minister was to install air conditioners in buildings…This was key to public efficiency," Lew wrote in a 2009 article for the *New Perspectives Quarterly*.

The team's objective was to show that is possible to provide the same or more comfort with less energy. The typical set point for office building indoor temperatures has for decades been 23°C in Singapore, where the yearly average outdoor temperature during the day is 29°C (84°F). But Schiavon and his team wanted to see what would happen when they turned up the thermostat.

They conducted five experiments in the summer of 2014, with 56 participants dressed in typical Singaporean office attire—long pants, a short-sleeved shirt, socks and close-toed business shoes—and assembled in a room at Nanyang Technological University featuring an open-office layout, with no cubicles.

During the 90-minute tests, researchers asked participants to gauge their comfort levels when temperatures were adjusted to 23°C (73.4°F), 26°C (78.8° F) or 29°C (84.2°F). Relative humidity was controlled at 60 percent, a typical indoor level in Singapore. In two of the tests (26 and 29°C), subjects were allowed to control air movement with personal electric fans if they wished.

The tests used smart, energy-efficient desk fans that run on more efficient, direct-current (DC) motors using between 3 and 17 watts, rather than alternative-current (AC) motors that use around 100 watts.

Increasing the indoor temperature set point to values in the range of 26-29°C (79-84°F) and simultaneously providing occupants with personally controllable fans could be a cost-effective, sustainable and energy-efficient option for providing thermal comfort in new and existing buildings in the tropics, said Schiavon.

"If applied to commercial building in Singapore, we could save up to 35 percent of the energy for air conditioning," he said.

"Moreover, we are now working on smart fans that can adapt to the environmental conditions and provide the needed comfort" said Schiavon, adding that his team has a provisional patent on a smart control for a system of fans and is applying for a full patent.

More information: S. Schiavon et al. Thermal comfort, perceived air quality, and cognitive performance when personally controlled air movement is used by tropically acclimatized persons, *Indoor Air* (2016). DOI: 10.1111/ina.12352

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