

ENERGY SAVINGS FROM EXTENDED AIR TEMPERATURE SETPOINTS AND REDUCTIONS IN ROOM AIR MIXING

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INTRODUCTION

Large amounts of energy are consumed by air-conditioning systems to maintain tight control of air temperature in rooms--a narrow range of temperature excursion from neutral, and a uniform temperature in the ambient space. However, both field and lab studies are showing that neither narrow range nor uniformity is really necessary for providing occupant comfort. Data from several large field studies shows occupants accepting a much wider temperature range than is typically applied in practice (Arens 2009). In addition, if occupants have access to a personal environmental control (PEC) system, the acceptable ambient temperature range can be further extended, to as much as 18-30°C (Zhang H 2009, Amai 2005, Zhang Y 2008). By targeting specific body parts, PEC systems produce equivalent comfort using much less energy than is needed to condition the entire ambient space.

Energy is also required consumed in fans and mixing diffusers to produce uniform room temperature conditions. To assure complete mixing, diffuser manufacturers specify minimum supply volumes that are as high as 50% of maximum volume. Some engineers have been successfully operating buildings well below these volume minima, and research is now underway to quantify the acceptability of their non-uniform environments to their occupants. Substantial fan energy savings are possible, and recent changes to energy standards (ASHRAE 2009) have begun to require a lower minimum.

This paper simulates the energy savings possible from through these two approaches to providing comfort in less tightly controlled spaces. Their savings are substantial and justify looking into how they might be incorporated into building design and operation.

METHODS

EnergyPlus simulations were performed to examine the energy implications of larger range of thermostat setpoints and low minimum supply volumes. A conventional HVAC building was simulated in the climates of San Francisco (mild coastal climate), Miami (hot and humid), Phoenix (hot and dry), and Minneapolis (hot in summer, cold in winter).

The building is based on a large office prototype developed by the U.S. Department of Energy. It is 111 x 278 ft with four stories and a basement, and each floor plate is 31,000 ft². The window to wall ratio is 0.4. Each floor consists of four perimeter zones of 15ft depth, and an interior zone (Figure 1). The floor-to-ceiling height is 13ft, and the floor-to-floor height is 15ft.

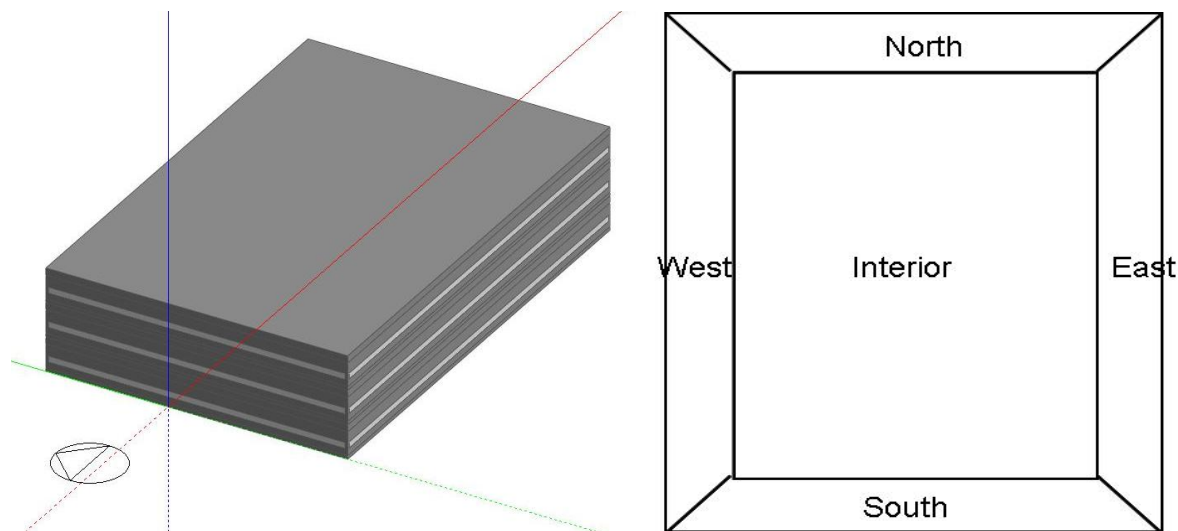


Figure 1. Configuration of the simulated building with perimeter and interior zones.

The model's internal load schedules for lighting, plug loads, and occupancy are typical for large offices. Peak power density for lighting is $1\text{W}/\text{ft}^2$, peak plug load is $0.75\text{W}/\text{ft}^2$, and peak occupancy is $200\text{ft}^2/\text{person}$.

The HVAC system is variable air volume (VAV) with reheat. There are four air handling units, one for each floor. A central boiler and centrifugal chiller provide the heating and cooling. Infiltration peaks at 0.25 air changes/hour when the ventilation system is off.

In the US, buildings are commonly designed using $21.5 - 24^\circ\text{C}$ ($71 - 75^\circ\text{F}$) as the temperature setpoints. In this study, this is considered the base case. The annual energy use intensity (EUI) changes caused by moving the cooling setpoints from 24°C to 25, 26, and 28°C were simulated independently with the heating setpoint fixed at 21.5°C . Similarly, the EUI changes from moving the heating set point from 21.5°C to 20.5, 19.5, 18.5, and 17.5°C were simulated with the cooling setpoint fixed at 24°C .

The minimum supply air volume of the VAV terminal units, as well as the heating and cooling setpoints, were parameterized to carry out this study. The HVAC system components were autosized to optimally meet design loads, so that the predicted annual EUI values include both effects of optimizing system size/efficiency, and of changes to the hours and intensity of operation.

RESULTS

A. Widening room air temperature setpoints

The annual energy savings compared to the base case are presented in Figure 2 for Minneapolis, San Francisco, Phoenix and Miami. Increasing the cooling setpoint by one degree from 24°C to 25°C results in energy savings of 7-15%. When the setpoint is expanded to 28°C , the energy

savings for three locations (except in Minneapolis) reaches 35 – 45%. In Minneapolis, the annual number of cooling hours is low so the potential for accumulated cooling savings at the highest setpoint is small.

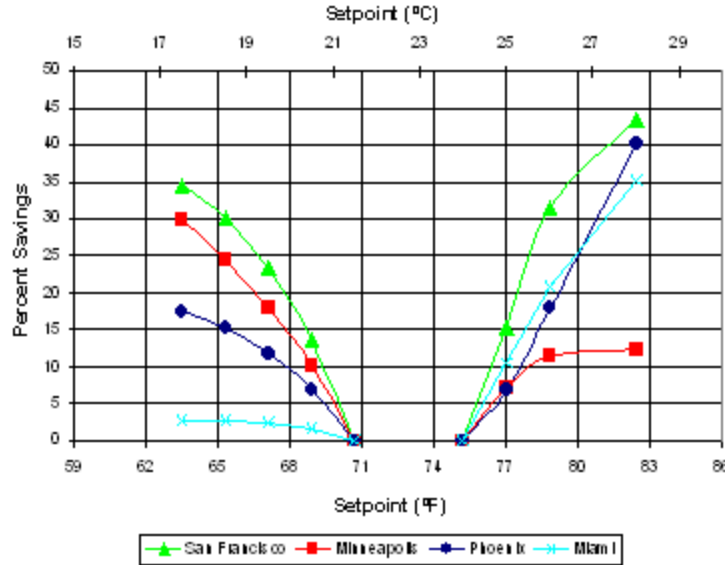


Figure 2. Percent energy savings for widened air temperature setpoints relative to conventional setpoint range in San Francisco, Miami, Phoenix, and Minneapolis.

Decreasing the heating setpoint by one degree from 21.5°C to 20.5°C results in energy savings of 7-14%, except in Miami. With the setpoint as low as 17.5°C, the total energy savings reach 17 – 35%. In Miami, the heating load is small year-round so there is not much potential for energy savings.

When both heating and cooling setpoints are expanded together, the savings can be estimated by adding the savings from each side.

B. Lowering the minimum supply volume

Figure 3 compares lowering the minimum supply volume from the base value of 30% to 20% and 10%. This comparison is done for San Francisco only. At the base-case design temperature setpoints (21.5 – 24°C), lowering the minimum supply volume to 20% and 10% saves 17% and 27%. At the expanded cooling setpoint (28°C) or heating setpoint (17.5°C), the energy savings reach 40 – 60% and 33 – 40%, respectively.

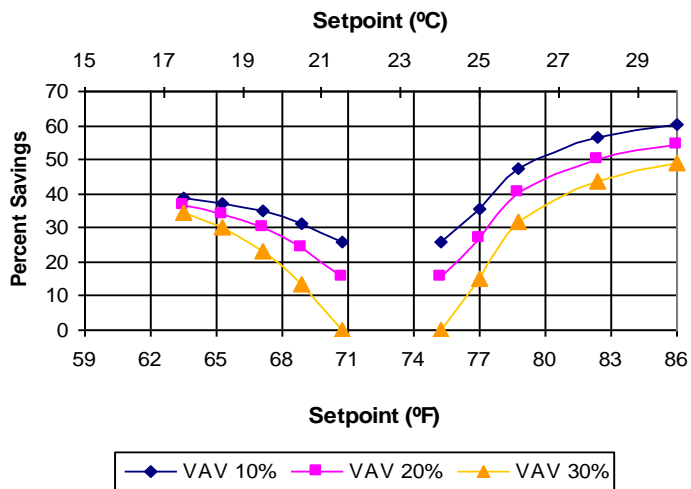


Figure 3. Annual energy use for the prototype in San Francisco with VAV minimum fractions at 10%, 20%, and 30%.

CONCLUSIONS

In a series of EnergyPlus simulations, we investigated the consequences of widening the indoor temperature range between thermostat settings for heating and cooling. The enlarged temperature range reduces energy use by lessening the cooling and heating loads in two ways. First, as a result of fewer heating and cooling hours, and second, as a result of a decrease in the magnitude of the difference between the setpoint and the outdoor temperature. The saving is about 10% for each degree Celsius increase or decrease in the setpoint.

In practice it may be possible to reduce the airflow minimum of VAV terminal units while still satisfying ventilation and mixing requirements. Performing the same setpoint-range simulations as above with VAV minimum fractions at 10%, 20%, and 30% of maximum capacity, minimum fractions of 10% and 20% produced ~25% and ~16% savings relative to energy use in the building with a minimum fraction of 30%.

The substantial savings justify further examination of these approaches in research, and their further application in energy and environmental standards and in practice.

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