General Services Administration
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GSA

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SMART CEILING FANS WHITE PAPER

Raising Cooling Setpoints Can Reduce Building Energy Costs by 11%

Raising cooling setpoints is a reliable way to save energy, but without mitigation, higher temperatures can compromise occupant comfort. Smart ceiling fans, which use sensors to measure temperature and adjust fan-speed, have been proposed as a way to preserve comfort as setpoints increase and temperatures rise. GSA's GPG program worked with the National Renewable Energy Laboratory (NREL) to provide guidance on how and where such fans might be best deployed. Using computer models to determine the energy-saving potential of ceiling fans, NREL found that raising the cooling setpoint by 4°F could reduce building energy costs by as much as 11%. They also found that to be cost-effective in most locations, installed costs must be less than $1.50/ft^2. Though modeled energy savings from simple ceiling fans are roughly equivalent to those from smart ceiling fans, there are reasons to believe that smart ceiling fans may be more efficient than their simple cousins. For example, smart ceiling fans can automatically turn on and off at predetermined temperatures or when a space is unoccupied. They also adjust their speed in response to temperature changes, ensuring an optimal cooling-to-fan-use ratio. As GSA's Total Workplace Initiative increases the prominence of open-office floor plans with low interior partitions, smart ceiling fans will be increasingly suitable for GSA facilities.

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

INTRODUCTION

Ceiling Fan Sizes and Area Served[1]

Small- and medium-sized fans will provide efficient cooling in a 4- to 6-foot diameter area, while larger fans are effective up to 10 feet. Multiple fans work best in rooms that are longer or wider than 18 feet.

Fan Diameter	Area Served (ft^2)	Max Power (W)	Max Power Density (W/ft^2)	# of fans needed (5,000 ft^2)
52 inch (4.3 ft)	225	14.8	0.07	22 fans
60 inch (5.0 ft)	400	21	0.05	12 fans
84 inch (7.0 ft)	900	63.8	0.07	6 fans

"Smart fans update a long-established technology, and have the potential to both save energy and offer comfort in today's air tight buildings."

— Kevin Powell
Director
GSA's GPG program
U.S. General Services Administration

TECHNOLOGY SPECIFICATIONS
ENERGY STAR Ceiling Fans

LOW

Minimum Airflow	1,250 CFM
Minimum Efficiency Requirement	155 CFM/watt

MEDIUM

Minimum Airflow	3,000 CFM
Minimum Efficiency Requirement	100 CFM/watt

HIGH

Minimum Airflow	5,000 CFM
Minimum Efficiency Requirement	75 CFM/watt

What Is This Technology?

CEILING FANS BOOST EFFICIENCY BY PERMITTING HIGHER COOLING SETPOINTS

Like traditional ceiling fans, smart fans hang from the ceiling and circulate air by either pushing it down or pulling it up. They do not themselves cool air; rather, they help cool human skin by enhancing evaporation and convective heat transfer. Ceiling fans save energy by allowing building managers to raise cooling setpoints, reducing the use of the HVAC's refrigeration compressor in favor of the ceiling fan's smaller, more efficient direct current (DC) motor. While the NREL study does not highlight specific savings unique to smart ceiling fans, several smart fan features may help maximize efficiency and operability. The smart ceiling fan assessed in this study, an Energy Star certified model that draws a maximum of 0.049 W/ft^2, has multiple speeds as well as temperature and humidity sensors that allow it to automatically adjust its activity to best help occupants stay comfortable in varying climate conditions. It can be remotely operated and coordinated with building automation systems (BAS) and it turns on and off automatically, depending on whether a room is occupied.

What We Did

MODELING APPROXIMATES ENERGY SAVINGS

GPG commissioned NREL to study the potential of ceiling fans to save energy in office buildings across U.S. climate zones. Site selection for measurement and verification (M&V) required an open-office floor plan with low partitions, ceilings at least 9 ft high, and a ceiling grid in which light fixtures would not interfere with fan operation. These prerequisites proved challenging to meet, so instead of performing traditional M&V, NREL used EnergyPlus simulations to model potential energy savings across climate zones in medium and large office buildings. In the computer models, the occupied cooling setpoint was raised in 2°F increments from 74°F to 84°F and the projected savings were calculated for different climates and in different energy markets. The nighttime cooling set-back temperature was maintained at 85°F and the supply air temperature was maintained at 55°F.

FINDINGS

4-DEGREE SETPOINT CHANGE YIELDS BETWEEN 4% AND 11% ENERGY SAVINGS Modeling showed the greatest savings in the first four degrees of setpoint change, from 74°F to 78°F, resulting in total annual building energy savings between 4% and 11%, or $0.07 and $0.22 per square-foot. The precise amount of savings depended on local climate and energy markets.

CEILING FANS ALLOW COMFORTABLE TEMPERATURES AT LEAST UP TO 78.8°F Although NREL's research focused on energy savings rather than occupant comfort, a 2013 Center for the Built Environment (CBE) study found that ceiling fans helped the majority of occupants remain comfortable in temperatures up to 78.8°F and revealed only minor discomfort at 82.4°F. The CBE study tested both smart fan control, where fan speed was influenced by temperature and humidity, and occupant control, where users regulated fan speed. There was little difference in comfort between the two control methods.

INSTALLED COST IS THE MOST SIGNIFICANT VARIABLE FOR PAYBACK In order to achieve payback in less than 10 years, the installed cost must be under $1.50/ft^2, given a 4-degree setpoint change.

CONSIDER INCORPORATING CEILING FANS INTO OPEN OFFICE DESIGNS Proper site selection is key for the effective use of ceiling fans. Target facilities with:

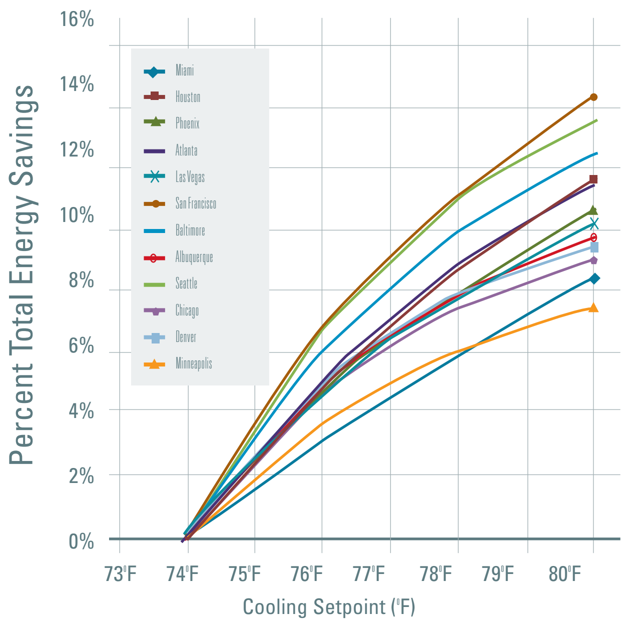
- Open-office floor plans with ceilings at least 9 feet high and interior/desk partitions less than 54 inches tall
- At least 2,000 cooling degree days and full daytime business hours
- No existing features, such as lighting fixtures or air conditioning ducts, that will interfere with fan blades
- Current cooling setpoint lower than 75 degrees, and no regulatory or technical prohibitions against raising it

Modeled Savings for Smart Fans

Energy savings for ENERGY STAR certified fans will be roughly equivalent

Energy Savings Across Climate Zones

Savings are greatest in San Francisco



Installed Cost Needed for a 10-year Payback

Assuming a 4°F increase in cooling setpoint

Location	Energy Savings kWh/ft^2/yr	Energy Cost Savings $/ft^2/yr	Installed Cost for 10-year Payback $/ft^2
Miami, FL	1.19	$0.117	$1.17
Houston, TX	1.41	$0.115	$1.15
Phoenix, AZ	1.47	$0.149	$1.49
Atlanta, GA	1.26	$0.131	$1.31
Las Vegas, NV	1.26	$0.119	$1.19
San Francisco, CA	1.39	$0.218	$2.18
Baltimore, MD	1.26	$0.140	$1.40
Albuquerque, NM	1.02	$0.105	$1.05
Seattle, WA	1.19	$0.095	$0.95
Chicago, IL	0.81	$0.075	$0.75
Denver, CO	0.84	$0.084	$0.84
Minneapolis, MN	0.71	$0.070	$0.70

CONCLUSIONS

These Findings are based on the white paper, "GSA's GPG program, Smart Ceiling Fans," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

Deployment Guidelines

IMPORTANT CONSIDERATIONS FOR DEPLOYING CEILING FANS

- **Fan placement.** Consult with lighting engineers, designers, and ceiling fan manufacturer to avoid interfering with lighting or causing occupant discomfort.
- **Fan size.** Larger ceiling fans can move more air than smaller fans. A 36- or 44-inch diameter fan will cool rooms up to 225 square feet, while fans that are 52 inches or more in diameter should be used in larger rooms.
- **ENERGY STAR certification.** ENERGY STAR fans move air 20% more efficiently, on average, than standard models. Look for models with the highest air-flow efficiency (CFM/watt) at every speed.
- **Motor.** There are two types of ceiling fan motors: those with sealed and lubricated ball bearings and those with bearings that rotate in an oil bath. Motors with sealed bearings require little or no maintenance whereas motors with oil baths need occasional service, such as adding oil.
- **Aesthetic appearance.** Products designed with aesthetic considerations in mind, which can be important to some occupants, come with a cost premium.
- **Blades.** Blades should be sealed from moisture to prevent warping, bubbling, or peeling. High quality blades are weighed and balanced prior to shipment and come in factory-matched sets. For this reason, they cannot be switched out with other fans.
- **Housing.** The housing is the decorative body of the fan that encloses the fan motor. Fans that use heavier materials, such as die cast metals, tend to vibrate less, provide more stability for longer downrods, and provide a good surface for high quality finishes.
- **Downrod.** Pay close attention to the downrod length of a fan. A fan will provide a greater wind chill effect if it is close to occupants than if it is far away. Fans that mount right next to the ceiling (so-called hugger models) are often highly inefficient because the fans have difficulty bringing in air behind the blades to push downward. Fans should be installed so their blades are no closer than 8 inches from the ceiling and 18 inches from a wall.
- **Noise.** Check the noise ratings of the ceiling fans. A noisy fan may offset the thermal comfort benefits, resulting in cool enough occupants who are bothered by fan noise.
- **Use.** Ceiling fans can only save energy if users raise thermostat setpoints during cooling season and lower the thermostat setpoints in heating season. Therefore a facility that uses ceiling fans without adjusting setpoints can have higher energy cost. Fans are circulation devices and cannot duplicate the wide range of functions traditional HVAC systems perform, including ventilation, filtration, humidification, dehumidification, heating, and cooling.

Footnotes

[1]Table data from a smart ceiling fan manufacturer.

Technology for test-bed measurement and verification provided by Big Ass Solutions.