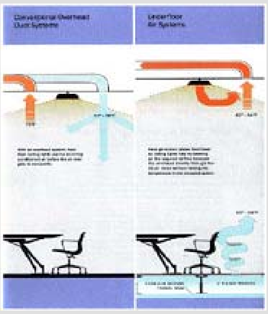
Implement under floor air systems to potentially achieve 5 - 34% annual HVAC energy savings and 67 - 90% annual churn costs savings, for an ROI of at least 115%

Under floor air is an innovation in engineering practice to deliver flexible, user-based services for air quality, thermal comfort and network access through a raised floor plenum rather than a ceiling plenum. By allowing reconfiguration of the density and location of diffusers and providing the benefits of floor air delivery supporting natural stratification, UFA offers gains in thermal comfort and air quality, increased energy efficiency, as well as enabling the use of operable windows in the workplace.

The major properties of UFA systems include:

- **Plenum for distribution:** Pressurized plenum (push) or distributed fans (pull) are major delivery styles in under floor air systems. The "push" mode relies on central fans and pressurized plenums with either unducted distribution of cooling and ventilation air from risers or partially or fully ducted distribution of air, supporting changing densities and locations of floor air diffusers with centralized, variable speed fans. The "pull" mode employs distributed, individual fans within the floor plenum to assist in air distribution.
- **Air delivery and removal:** Supply air is delivered through easily relocatable floor air diffusers and occasionally through desktop air diffusers. Return air is removed at the ceiling to maximize the vertical airflow patterns for pollution removal and stratification benefits.
- **User control:** UFA systems offers the opportunity to provide individual control of thermal and air quality conditions through the location and density of diffusers, volume dampers, directional diffusers and at times, temperature control through mixing.



	Conventional practice	Improved practice
Thermal and Air Delivery	Ceiling-based; typically systems are combined.	Under floor-based; potentially separate systems.
Diffuser Locations	Fixed density and location in the ceiling	Changing density and location in the floor, desk, partition.
Stratification and Mixing	Eliminates stratified zone, distributes air pollutants.	Stratified zone remains above conditioned zone for energy conservation. Low supply and high return reduces mixing and pollutant distribution.
HVAC Control	Central control to maintain uniform conditions of temperature and ventilation.	Central and individually controlled micro-zones. Users control diffuser location/density, potential for control of air direction, volume, and speed, temperature, and outside air.

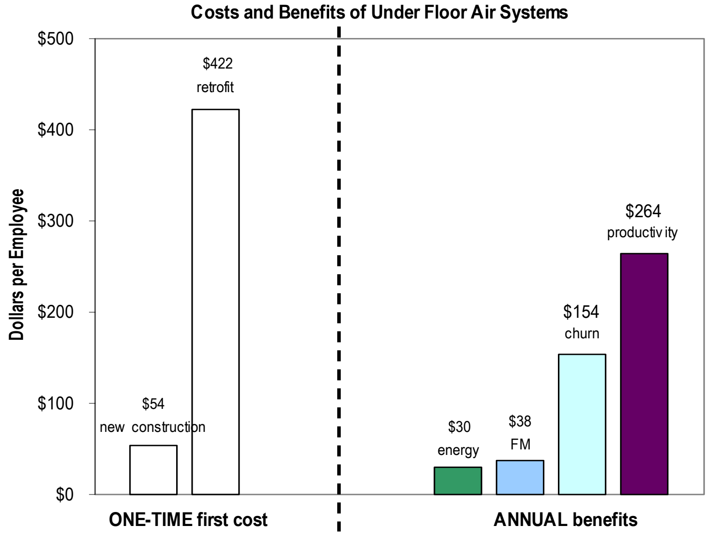
UFA systems pay!

Twelve studies have shown that UFA systems can pay for themselves in less than one year due to energy, productivity, churn, and facility management benefits.

CMU's BIDS™ demonstrates that UFA yields annual energy cost savings of $30 per employee ($0.14/ft²), productivity gains of $254 per employee, churn cost savings of $154 per employee, and facility management savings of $38 per employee ($0.19/ft²), for total savings of up to $486 per employee annually*.

With a one-time first cost premium of $54 per employee for new construction and $422 per employee to modify existing buildings, the average ROI for an investment in UFA is 900% for new buildings and 115% for retrofits.   .

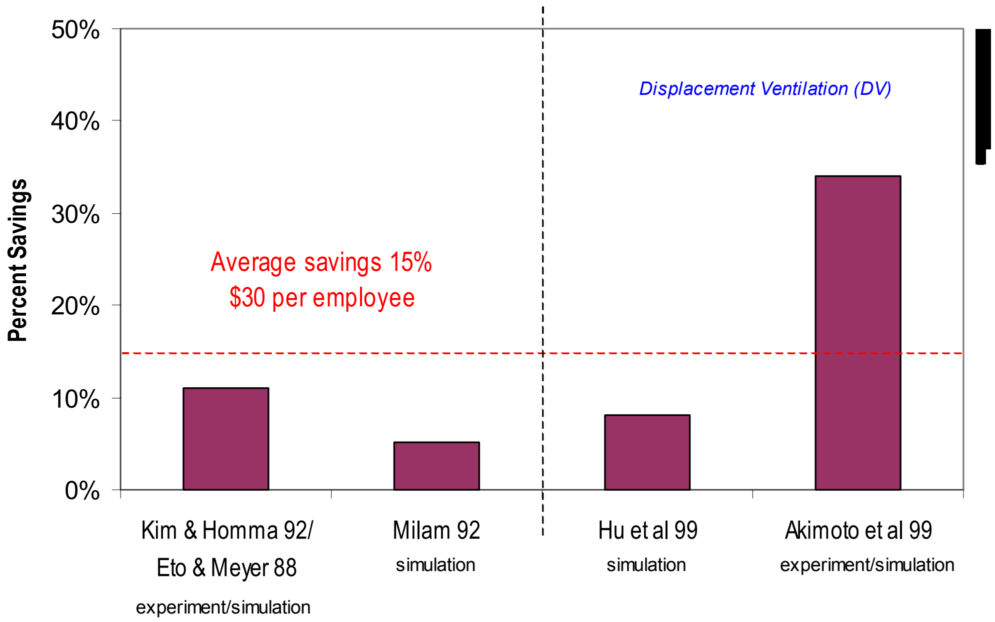
*Using BIDS™ baseline assumptions



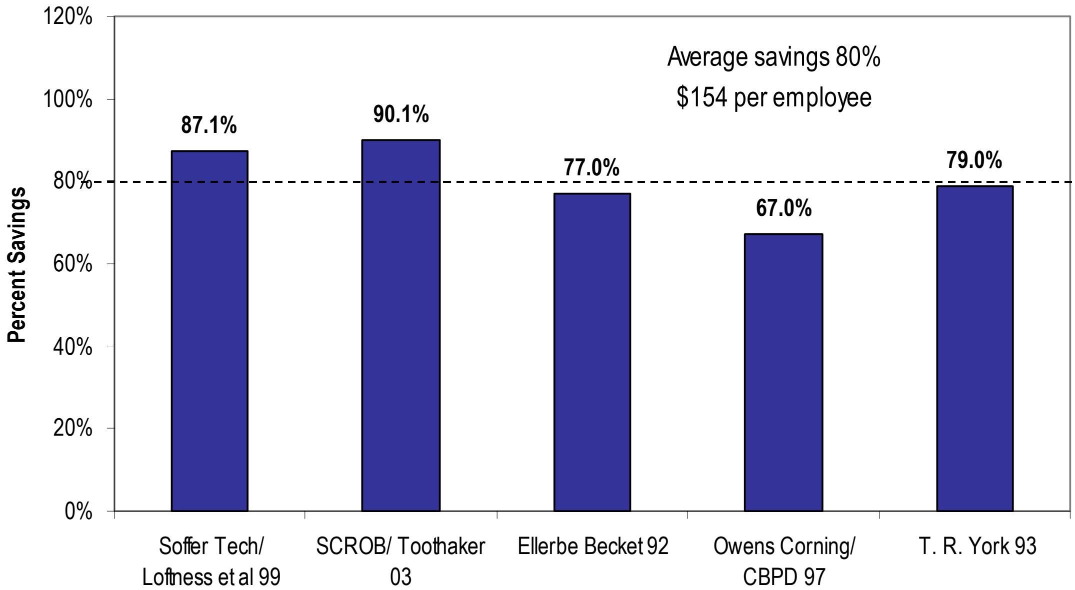
Benefits of UFA systems

CMU's BIDS™ identifies four case studies that indicate an average 15% reduction in annual HVAC energy consumption due to UFA systems. Five studies demonstrate an average 80% reduction in annual churn cost due to UFA. (Churn cost is the cost of office moves and changes). Two studies report first cost savings of $0.43 to $2.00 per square foot for UFA systems, as compared to ceiling-based systems. One case study identifies annual facility management staffing cost savings of $0.19 per square foot and one study shows an individual productivity improvement of 0.7%, given underfloor air delivery.

Annual HVAC Energy Savings from UFA



Annual Churn Cost Savings from UFA



BIDS™ Case Study Examples of Under Floor Air Systems

Milam 1992

In a 1992 simulation study, Milam compares an underfloor air distribution system with a conventional overhead VAV system for a 26,400 square foot prototypical office building with standard loads. Equipment selection and layouts for 2 different climatic conditions (Atlanta and Chicago) are analyzed. For the Atlanta climate, Milam identifies first cost savings of $0.43 per square foot and energy savings of 1.55kWh per square foot for underfloor air systems. Energy savings are attributed to improved ventilation effectiveness, smaller and less equipment, and reduced need for cooling of outside air, higher supply temperature with UFA. Similar savings were identified for the Chicago building, with $0.49 per square foot first cost savings and 0.95 kWh per square foot energy savings.

Milam, J.A. (1992) Underfloor Air Distribution HVAC Analysis – Prepared for USG Interiors Inc. Environmental Design International.

Hu et al 1999

In a 1999 simulation study, Hu et al examine the difference in fan, chiller and boiler energy use between a floor-based displacement ventilation system and a conventional ceiling-based mixing ventilation system in a small office, a classroom, and an industrial warehouse. The 204 square foot office is modeled with each ventilation system in five climatic situations (cold; hot and dry; hot and humid; moderate; and maritime). Simulation results indicate that the ceiling-based system uses approximately 86 kWh/m2 (8kWh/sf) annually, while the floor-based displacement system uses approximately 79.5 kWh/m2 (7.4kWh/sf) annually, a savings of 8%. The results are consistent for each climate condition.

Hu, S., Chen, Q., Glicksman, L.R. (1999) Comparison of Energy Consumption Between Displacement and Mixing Ventilation Systems for Different U.S. Buildings and Climates ASHRAE Transactions, Vol.2, pp. 453-464.

Owens Corning / CBPD 1997

In a 1997 building case study of the Owens Corning headquarters in Toledo, OH, the CBPD research team identifies 67% churn savings due to the incorporation of a full kit of user-based infrastructural components that ensures individual comfort, organizational effectiveness, and maximum flexibility. The 400,000sf headquarters building uses individualized, relocatable air diffusers fed by a pressurized underfloor plenum rather than conventional ceiling-based HVAC, structured wiring, poke through. This combination of flexible systems has resulted in a 67% reduction in churn costs, from $450 per move in the previous building to $150 per move in the new building. With 1300 employees and 1600 moves per year in the building, the reduction in churn results in $480,000 savings for the company.

CBPD (1997) The Owens Corning Building Studies. Center for Building Performance and Diagnostics (CBPD), Carnegie Mellon University, Pittsburgh, PA.

Soffer Tech Building / Loftness et al 1999

In a 1999 simulation and building case study of the Soffer Tech office building in Pittsburgh, Loftness et al identify an 87.1% churn cost savings for every 100% churn, as well as 3.3% electricity savings and 21.6% natural gas savings annually, due to the use of flexible raised floor infrastructures (HVAC, power, and networking) as compared to a conventional ceiling-based VAV system and poke-through wiring.

Loftness, V., Matthew, P., Gardner, G., Mondor, C., Paul, T., Yates, R., Dellana, M. (1999) Sustainable Development Alternatives for Speculative Office Buildings: A Case Study of the Soffer Tech Office Building. Center for Building Performance and Diagnostics, Carnegie Mellon University.

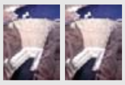
THE NATIONAL IMPACT

Energy Conservation

With a total area of 12 billion square feet, U.S. office buildings use over 135 billion kWh for heating, ventilation, and air conditioning each year. At the 2003 U.S. average energy cost of $0.08 per kWh, the potential savings from implementing under floor air systems in 35% of office buildings is more than **$600 million** each year. Over **7.56 billion kWh** would be saved annually—an amount of energy equal to:

One-tenth the annual energy production of the Three Gorges Dam

1.89 times the annual energy production of the Hoover Dam



The annual energy use of 280,000 U.S. households
(= 10,000 houses)

The gasoline used by 337,000 cars in a year
(= 10,000 cars)

Energy - Associated Benefits

The annual energy savings of **7.56 billion kWh** achieved by implementing UFA systems in 35% of U.S. office buildings would generate valuable reduction in **emissions** and **water consumption** due to power generation, for a total additional savings of **$283.25 million annually**, and one-time **peak load** reduction with a value of **$302.4 million.**

Peak Load Reduction

252 MW
with an estimated value of
$302.4 million

(6% peak demand reduction)

Emissions Reductions

Pollutant	*Annual reduction*	*Annual cost savings*
CO_2	10.5 billion lbs	$70 million
SO_2	45.7 million lbs	$106 million
NO_X	22.4 million lbs	$74 million
PM_{10}	0.98 million lbs	$2.13 million

Water Consumption Reduction

15.1 billion gallons / year
with an estimated value of
$30.2 million annually

Additional Benefits

Given the average productivity benefit of $264 per employee, the average churn benefit of $154 per employee, and the average facility management benefit of $38 per employee, the total savings achieved by providing under floor air to 35% of U.S. workforce is **$957 million** annually.

All references and assumptions for these data are available online