

Design & Technology  
Energy & Environmental Planning  
Construction Consulting

Barry Donaldson & Associates

## **SUSPENDED CEILINGS VS. OPEN PLENUM - LIFE CYCLE STUDY**

Ceilings & Interior Systems Construction Association

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## **SUSPENDED CEILINGS VS. OPEN PLENUM - LIFE CYCLE STUDY**

### **1. Introduction**

The design of commercial ceiling systems is influenced by a number of factors, with a particular focus on the need to accommodate air distribution ducts and plenums, power and telecom wiring, fire & life safety systems, security systems and an increasingly complex and dense distribution of horizontal systems. As buildings and businesses undergo more unpredictable and rapid change, systems are constantly being moved, upgraded and modified requiring greater ease of reconfiguration and flexibility than ever before. The rate of change in office environments, or 'churn rate' is a function of changing technology, personal mobility, and the reconfiguration of workstations. The International Facilities Managers Association (IFMA) defines churn as the number of moves in a year expressed as a percentage of the number of offices occupied. "In the 2002 IFMA Project Management Benchmarks report, the main churn rate across the surveyed organizations was 41 percent."<sup>1</sup>

These requirements for flexibility may dictate either a suspended ceiling or an open plenum. A suspended ceiling system may provide a finished interior that allows access to systems located in the plenum space above, and an open plenum may provides a ceiling that leaves systems exposed for ease of accessibility.

The life cycle cost study, initiated by the Ceilings and Interior Systems Construction Association (CISCA), looks at the cost and performance benefits of suspended ceiling vs. open plenum designs for two building types - offices and retail food stores. The study evaluates differences in construction and operating costs, as well as performance issues such as fire integrity, energy performance, ease of maintenance, lighting and acoustic performance, and other design considerations.

### **2. Life Cycle Costs**

The life cycle cost analysis of the office and food store examples includes initial construction costs of suspended ceiling vs. open plenum designs, as well as annual operating costs. Operating costs of HVAC and lighting systems (i.e. re-lamping, utilities, energy costs), maintenance costs such as periodic maintenance, repair and cleaning, and the cost of reconfiguration (moves-adds-changes). Construction costs are based on data from RS Means<sup>2</sup> and operating costs are based on data from Building Owners and Managers Association International (BOMA)<sup>3</sup>.

Construction and operating costs are also evaluated for different regions to show a range of different material costs, labor markets, climate regions, and energy costs. The different regions included in the study are Chicago (climate zone 5), Charlotte and Oklahoma City (climate zone 7), Orlando and Phoenix (climate zone 9).

Energy costs for the suspended ceiling and open plenum designs are analyzed for each of these different regions based on computer calculations and comparisons of building loads, energy, and cost.<sup>4</sup>

### **3. Prototype Office and Food Store**

The study is based on an evaluation of typical offices and food stores as examples of two very different building and construction types. The 'prototype' buildings are based on average data from a number of sources, including information from the U.S. Department of Commerce, the U.S. Department of Energy (DOE), the Environmental Protection Agency (EPA), and Building Owners & Managers Association (BOMA). Construction characteristics such as equipment and lighting loads (watts/sq.ft.), and envelope thermal performance are based on minimum code criteria described in ASHRAE Standard 90.1 2004 "Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings".

#### **3.1 Prototype Office**

The prototype office building/space is assumed to be low-rise/mid-rise type I, non-combustible construction of structural steel with a metal deck and concrete floor/ceiling system. According to the 2006 Building Energy Data Book, the typical mid-rise office is 6 to 7 stories, and 90,000 to 137,000 sq.ft. (approx. 12,800 to 22,800 sq.ft./floor), with 40-50% glass. The prototype office building/space is assumed to be a 15,000 sq.ft. typical floor of a multistory building with a nine (9) foot floor to ceiling height and an open plan layout.

#### **Suspended Ceiling System**

The suspended ceiling example is assumed to be a standard 2x2x3/4" ceiling tile with a narrow profile suspension system (9/16") and a non-fire rated assembly (figure 1). The open plenum example is assumed to have the underside of the floor slab above to be painted.

#### **HVAC**

For the suspended ceiling and open plenum designs, the office systems such as HVAC, power and telecommunications are assumed to be provided from the ceiling. In the suspended ceiling examples, the HVAC air distribution is ducted air supply and plenum air return. In the open plenum ceiling examples, the HVAC air distribution is ducted supply and return. Typical HVAC systems include central heating from a gas boiler and cooling from an electric centrifugal chiller, with constant volume or variable air volume (VAV) air distribution.<sup>5</sup> The typical office annual energy use is about 90,000 Btu/sf/yr<sup>6</sup> and average operating costs are about \$6.00/sq.ft., of which \$1.80/sq.ft. is for utilities.<sup>7</sup>

#### **Electrical and Telecommunications**

For the suspended ceiling example electrical wiring is MC cable and telecommunications wiring is plenum cable distributed above the ceiling, without cabletrays. In the open plenum example, power wiring is in conduit and telecommunications cable is plenum cable distributed in cabletrays. For both examples, telecommunications cable is assumed to be plenum rated to meet the requirements of NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems 2002"

## Lighting

For the suspended ceiling example light fixtures are assumed to be 2x2 u-tube fluorescent, recess mounted fixtures with acrylic lenses. Return air troffers are assumed for half of the light fixtures.

### 3.2 Prototype Food Store

The prototype food store building/space is assumed to be type II construction of a one-two story masonry structure with bar joists and a metal deck and concrete floor/ceiling system. Although the typical food store is a small supermarket of about 5,000 sq.ft., there has been a trend since the 1960's for larger supermarkets that dominate much of retail food sales in the United States. "By 1998 the median average store size was 40,483 sq.ft, up from 38,600 sq.ft. in 1966." "A typical new store in 1998 was just over 57,000 sq.ft, up from about 52,400 sq.ft. in 1997." <sup>8</sup> The prototype food store is assumed to be larger than the average, but smaller than the typical large supermarket, with a 10,000 sq.ft. area (100 ft x 100ft).

### Suspended Ceiling System

The prototype food store has an eighteen foot (18 ft) floor to ceiling height. The suspended ceiling example includes a standard 2x4x1/2" ceiling tile and an exposed grid suspension system (15/16") in a non-fire rated assembly (figure 2). The open plenum example is assumed to have the underside of the floor/roof slab above to be painted.

### HVAC

For the suspended ceiling and open plenum designs, HVAC, power and telecommunications are assumed to be provided from the ceiling. In the suspended ceiling examples, the HVAC air distribution is ducted air supply and plenum air return. The supply and return air grilles/registers are located in the suspended ceiling. In the open plenum ceiling examples, the HVAC air distribution is ducted supply and return. The typical HVAC system is a rooftop packaged air conditioner, with gas heating and electric dx cooling. Air distribution is constant volume.<sup>9</sup>

### Electrical and Telecommunications

For the suspended ceiling example electrical wiring is MC cable and telecommunications wiring is plenum cable distributed above the ceiling, without cabletrays. In the open plenum example, power wiring is in conduit and telecommunications cable is plenum cable also without cabletrays, since there is very little telecom wiring in food stores. For both examples, telecommunications cable is assumed to be plenum rated to meet the requirements of NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems 2002"

## Lighting

For the suspended ceiling example lighting is assumed to be recessed H.I.D. fixtures, 250W. For the open plenum example lighting is assumed to be H.I.D. fixtures with pendant mounts attached to the underside of the floor slab/roof above.

Typical floor plans and sections illustrate the office and food store building/space types (figure 3 and 4)



**4. Costs** Figure 1 - Office Suspended Ceiling  
**Ceiling Plenum Design**

**Construction**



Figure 2 - Food Store Suspended Ceiling

**Construction Suspended vs. Open**

Construction and operating costs are analyzed for the office and food store examples based on data from RS Means "Construction Cost Data 2007". The construction costs of the suspended ceiling vs. open plenum designs include the following:

- Suspended Ceiling System acoustical tile and suspension system
- Painting - exposed slab/floor above and mechanical systems (ductwork)
- HVAC Systems - fans, supply / return air ductwork, diffusers/grilles
- Electrical - wiring distribution, conduit, cabletrays
- Lighting - light fixtures, pendant, attachments

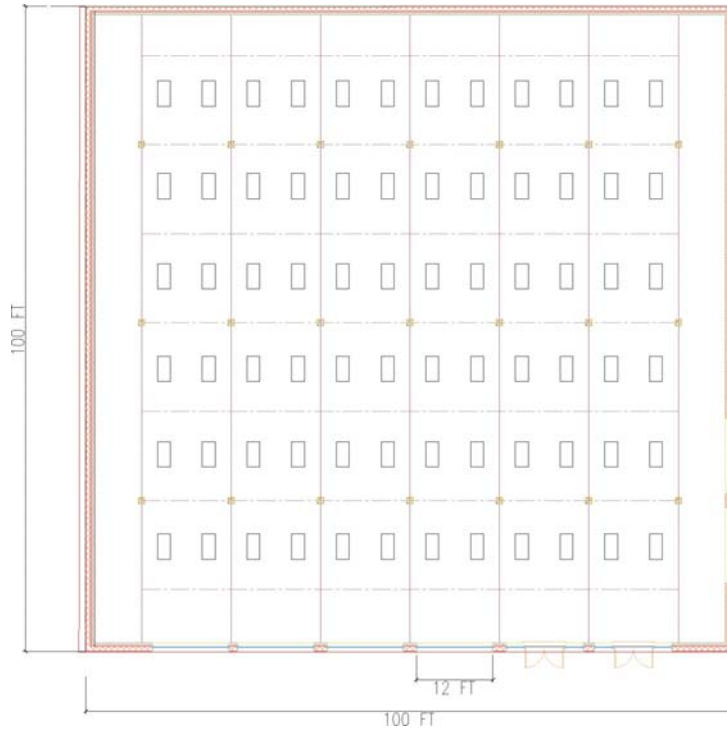


Figure 3 - Typical Food Store Plan

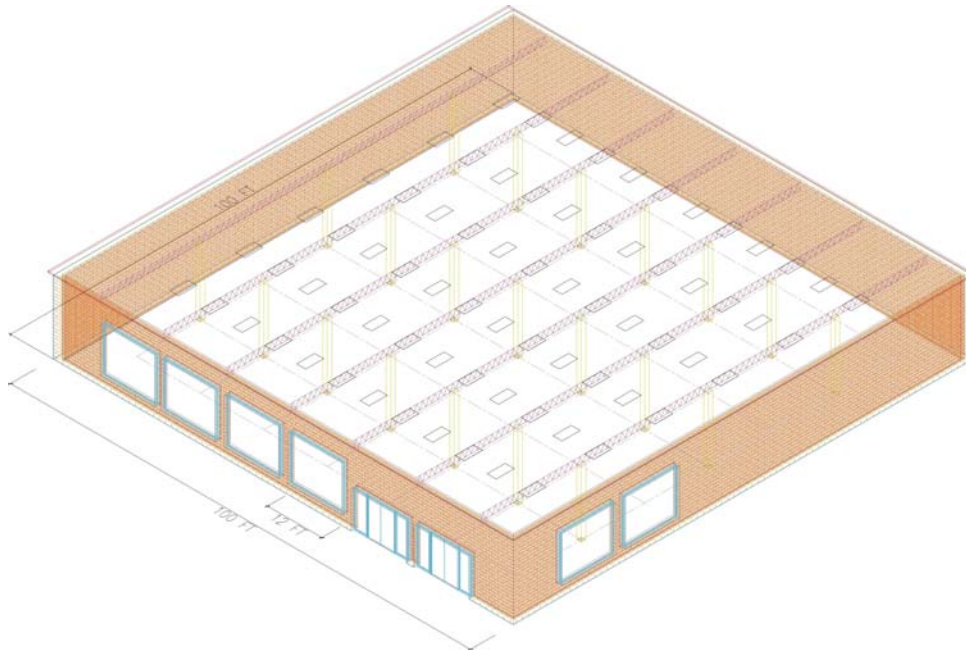


Figure 4 - Typical Food Store Isometric

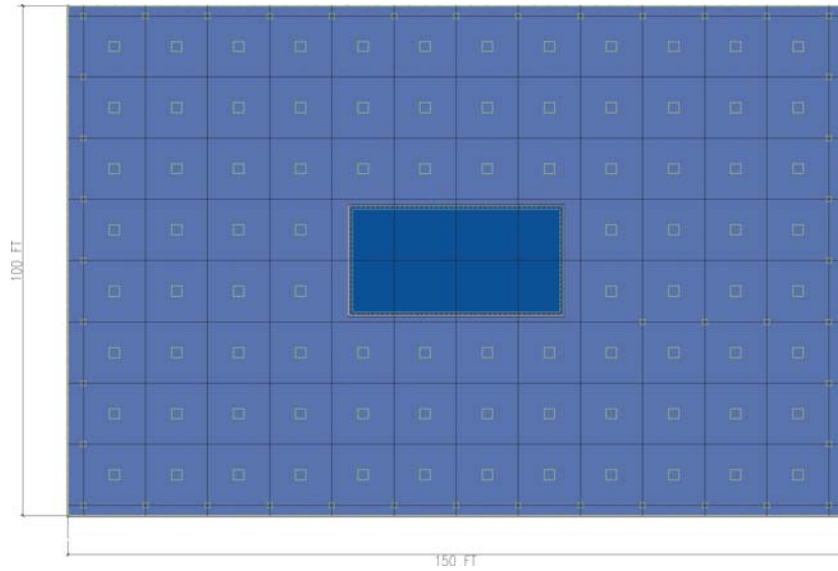


Figure 5 - Typical Office Plan

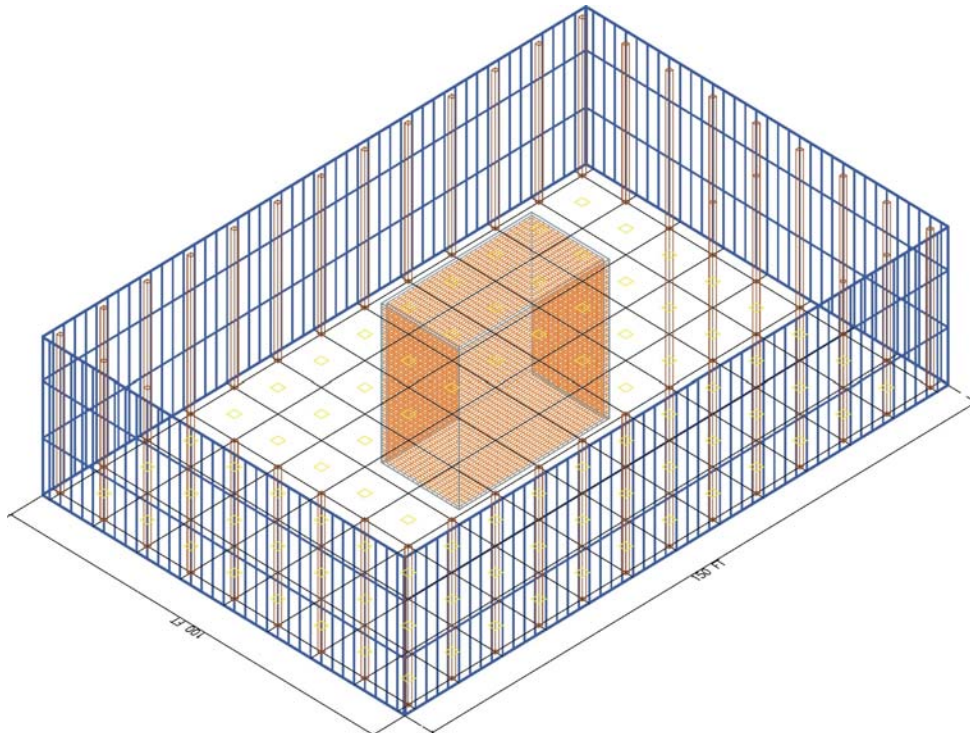


Figure 6 - Typical Office Isometric

The construction costs for the different regions are summarized in the following table, with a more detailed breakdown included in the appendix. Construction costs are highest in Chicago and Phoenix and lowest in Charlotte and Orlando.

Construction Cost	Chicago	Charlotte	Oklahoma	Orlando	Phoenix
Office Building					
Suspended Ceiling	\$164,636	\$95,247	\$99,528	\$96,453	\$108,152
Open Plenum	\$141,234	\$79,670	\$86,760	\$79,062	\$92,840
total cost increase	\$23,402	\$15,577	\$12,768	\$17,391	\$15,312
cost/sq.ft. Increase	\$1.56	\$1.04	\$0.85	\$1.16	\$1.02
% increase	16.6%	19.6%	14.7%	22.0%	16.5%
Food Store					
Suspended Ceiling	\$120,724	\$72,780	\$76,250	\$74,204	\$82,484
Open Plenum	\$114,808	\$67,493	\$73,259	\$67,118	\$78,055
total cost increase	\$5,916	\$5,287	\$2,991	\$7,086	\$4,429
cost/sq.ft. Increase	\$0.59	\$0.53	\$0.30	\$0.71	\$0.44
% increase	5.2%	7.8%	4.1%	10.6%	5.7%

The office building cost increases range from almost 15-20%, whereas the increase for the food store is an increase of about 4-10%. Detailed cost breakdowns are included in the Appendix. The construction cost premium for a suspended ceiling is greater for the office building than for the food store because it is a higher quality ceiling with a 2x2 grid and tile and a narrow profile suspension grid.

In general, the additional cost of the suspended ceiling, flex ducts, and cabletray is only partially offset by the additional costs of a return fan, return air ductwork, and conduit for the open plenum design. The cost of recess mounted light fixtures in the suspended ceiling is relatively close to the cost of pendant mounted light fixtures in the open plenum design.

To justify the additional cost of the suspended ceiling design, it must be offset by enhanced performance and reduced cost of operations such as lower energy cost, easier maintenance, and reduced cost of renovation and reconfiguration.

#### 4. Operating Costs of Suspended Ceiling vs. Open Plenum Design

Operating costs, including maintenance and energy costs, are analyzed from data included in the 2007



BOMA Experience Exchange Report and from analysis of energy use for the different regions. Information related to energy costs and HVAC equipment sizing is determined from computer simulations of the two building types for each of the regions based on local weather and utility data. Utility data was reviewed for each region to insure that consumption (kWh) and demand (kW) charges reflected current rates and tariffs for small to medium size commercial customers.

Although the BOMA data includes utility costs for the different regions, the energy/cost analysis is specific to the building types and layouts of the study to obtain a more accurate comparison of the trade-offs between the suspended ceiling and open plenum designs.

The energy use for the suspended ceiling examples is expected to be somewhat lower because of the use of a return air plenum with low static pressures and fan horsepower, instead of ducted air return with higher static pressures and fan horsepower. The suspended ceiling with a return air plenum is also more effective in removing heat of lights from the space, and therefore, reducing the air conditioning load on the space.

The suspended ceiling examples typically have higher (and more uniform) ceiling reflectances (i.e. 70% reflectance) than the open plenum examples with layers of equipment. The open plenum examples, with uneven ceiling and somewhat darker ceiling surfaces have somewhat lower light reflectance (i.e. 50% reflectance). These variables are included in the energy/cost model.

#### 4.1 Maintenance Costs

The BOMA average operating costs for 2007 for the different regions is summarized in the following table.

	Chicago	Charlotte	Oklahoma City	Orlando	Phoenix
cleaning	\$1.60	\$1.01	\$1.18	\$1.08	\$0.85
repair / maintenance	\$1.80	\$1.01	\$1.19	\$0.73	\$1.42
utilities	\$1.51	\$1.51	\$2.26	\$2.57	\$1.88
roads / grounds	\$0.09	\$0.49	\$0.24	\$0.37	\$0.08
security	\$0.76	\$0.37	\$0.15	\$0.19	\$0.48
administration	\$1.53	\$1.03	\$1.05	\$1.12	\$1.54
total operating expense	\$7.22	\$4.93	\$6.04	\$6.05	\$6.13

Although it is difficult to define different requirements and costs of maintenance for a suspended ceiling vs. open plenum design, the analysis assumes there may be savings in not having to periodically clean ducts, pipes and raceways that may collect dust, by eliminating the need to paint or finish exposed equipment and systems, and by less overhead maintenance activities in general.

For the open plenum design to achieve a somewhat comparable architectural treatment with a

finished suspended ceiling, the open plenum design is assumed to be painted. The cost analysis assumes a painted open plenum ceiling and an additional 10% maintenance cost of cleaning and repainting (i.e. ranging from \$0.07-0.15/sq.ft.). This may be a particular concern in offices where there is more attention paid on maintaining acceptable levels of indoor air quality (i.e. prevent dust buildup on surfaces of equipment, ductwork, etc.) and a clean appearance in general. This is also a concern for any projects that may be considering LEED certification where issues of environmental stewardship are important, or in particular for concerns of health and cleanliness in food stores.

## 4.2 Energy Costs

The energy / cost analysis of the prototype office and food store located in each region includes information about the different building characteristics, systems, and operating schedules, as well as different construction costs of the suspended ceiling vs. open plenum designs.

The energy / cost analysis compares the energy cost/sq.ft. of the suspended ceiling and open plenum designs, a life cycle cost analysis (internal rate of return, life cycle payback, and simple payback), and indicates the reduced environmental emissions from the reduced energy use (CO<sub>2</sub>, SO<sub>2</sub>, and Nox data is included in the Appendix). The results of the energy / cost analysis is summarized in the following table.

Building	Chicago		Charlotte		Oklahoma City		Orlando		Phoenix	
	Ceiling	Plenum	Ceiling	Plenum	Ceiling	Plenum	Ceiling	Plenum	Ceiling	Plenum
<b>Office</b>										
Energy (Btu/sf/yr)	52,563	55,175	47,482	50,664	48,697	51,724	48,225	51,668	48,352	51,606
Energy Cost (\$/sf/yr)	\$1.42	\$1.53	\$2.15	\$2.32	\$0.49	\$0.53	\$1.47	\$1.56	\$0.90	\$0.97
Energy Cost Savings (5)	7.2%		7.3%		7.6%		5.8%		7.2%	
Internal Rate of Return	283.2%		<0%		129.4%		184.9%		<0%	
Life Cycle Payback	0.4 yrs		0.3 yrs		0.9 yrs		0.6yrs		0.1 yrs	
Simple Payback	0.3 yrs		0.3 yrs		0.7 yrs		0.5 yrs		0.1 yrs	
<b>Food Store</b>										
Energy (Btu/sf/yr)	106,281	116,506	82,775	96,468	91,119	102,895	89,117	105,256	87,842	101,578
Energy Cost (\$/sf/yr)	\$2.34	\$2.81	\$2.69	\$3.28	\$2.05	\$2.38	\$2.92	\$3.42	\$1.60	\$1.88
Energy Cost Savings (5)	16.7%		18.0%		13.9%		14.6%		14.9%	
Internal Rate of Return	84.3%		140.6%		135.8%		73.0%		79.6%	
Life Cycle Payback	1.4 yrs		0.8 yrs		0.8 yrs		1.6 yrs		1.5 yrs	
Simple Payback	1.1 yrs		0.6 yrs		0.6 yrs		1.2 yrs		1.1 yrs	

The rate of return, life cycle payback and simple payback data assumes relatively conservative cost increases for energy of 5%, a cost of capital of 10%, and an interest rate of 8%.

## 5. Conclusion - Life Cycle Cost of Suspended Ceiling vs. Open Plenum Designs

For the prototype office, the initial construction cost of the suspended ceiling design can range from almost 15% to 22% more than for an open plenum design. For the prototype food store, the initial construction cost of the suspended ceiling design can range from about 4% to over 10% more than for an open plenum design. However, the energy and maintenance savings justify the use of a suspended ceiling plenum, with extremely short simple paybacks of one to eight months for the office design, and 7 to 13 months for the food store design.

In addition to operating cost savings, the reduced cost of 'churn' including simple moves to and from existing workplaces, relocation of furniture, and reconfiguration of offices and workstations can be significant. The average cost of simple moves is about \$191 per move, for relocation of furniture it is about \$712/move, and for reconfiguration that requires construction it is about \$2,100 per move.<sup>10</sup>

Suspended ceiling assemblies provide a flexible and accessible ceiling finish to allow for ease of reconfiguring building systems to accommodate changing work and space requirements. In office spaces, it is easier and less expensive to move flexible, modular components that can be unplugged and plugged into a different location with minimum construction. One of the primary reasons for the use of suspended ceiling systems is that they provide an architectural finish that provides acoustical performance and a fire rated assembly to create a plenum for the systems above, with the ability to reconfigure those systems above the ceiling as office workstations below are moved and relocated. The use of flexible ductwork, modular power and telecommunications cabling with UL rated connectors, light fixtures with modular 'pigtail' connections, and return air troffer light fixtures allows for easier and less expensive changes and reconfiguration.

Open plenum ceilings require that HVAC, power and telecommunications systems have some architectural treatment or finish (e.g. metal or gypsum enclosure, painting, etc.), that they be fire rated or enclosed in a fire rated assembly. Fixed components such as rigid metal ductwork, rigid metal conduit, hard wired power and telecommunications connections, and fixed mounted light fixtures are more difficult and expensive to move and reconfigure.

The environmental benefits of the suspended ceiling designs include reduced environmental emissions from lower energy use (CO<sub>2</sub>, SO<sub>x</sub>, and NO<sub>x</sub>) which are shown in the Appendix. For office spaces in particular, the potential benefits of being able to reconfigure air distribution and lighting with the changing layout of workstations can provide better control of indoor air and lighting quality.

Energy efficiency and indoor environmental quality are important considerations for certification with

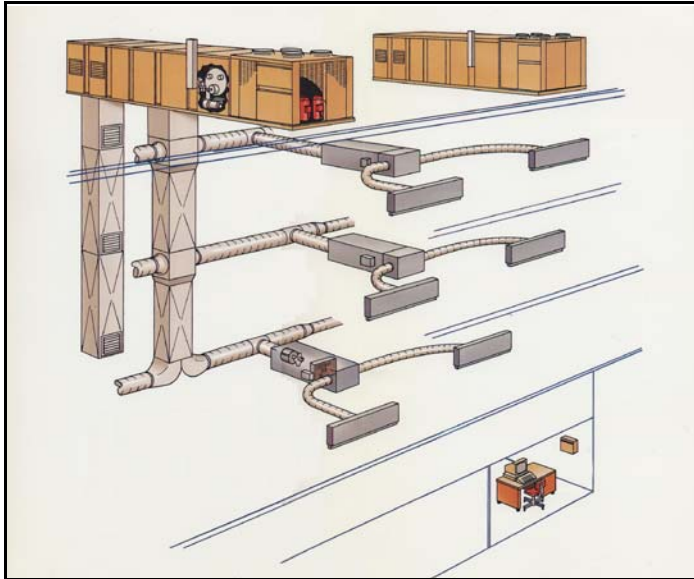
the USGBC “LEED Green Building Rating System”. The magnitude of the energy savings is 5.8-7.6% for the office design, and 13.9-18% savings for the food store design. This is a significant improvement towards achieving additional LEED credits of 1 to 3 points (EA Credit 1 - Optimize Energy Performance” - 10.5% reduction for 1 point, 14% reduction for 2 points, 17.5% reduction for 3 points).<sup>11</sup>

The ability to provide acoustical separation, privacy and sound attenuation, although not included in LEED, are also important indoor environmental issues for offices and retail food stores.

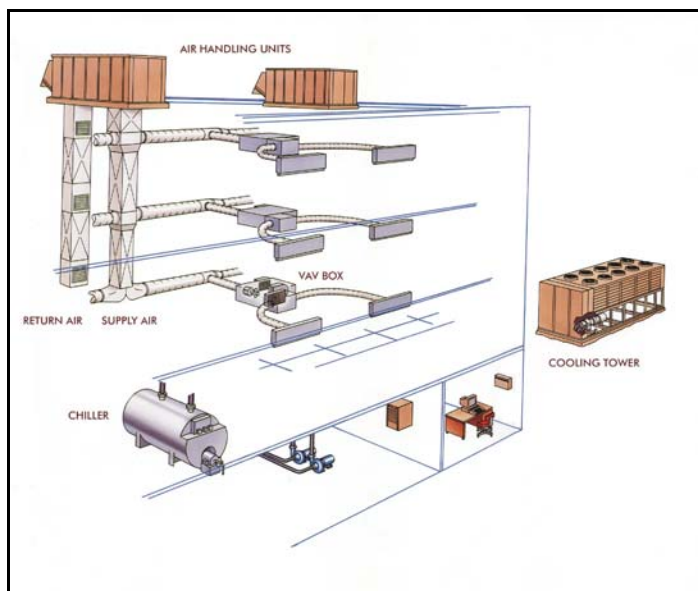
Today, the availability of many different suspended ceiling products, systems, and designs such as floating ceilings, curved ceilings, and transparent/translucent ceilings provides a great deal of flexibility for different applications.

## APPENDIX

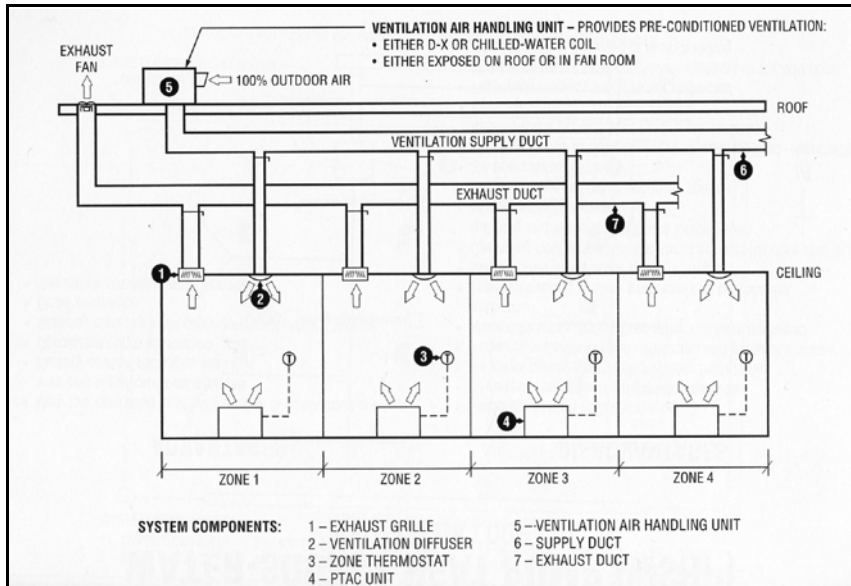
### A1 HVAC System Schematics



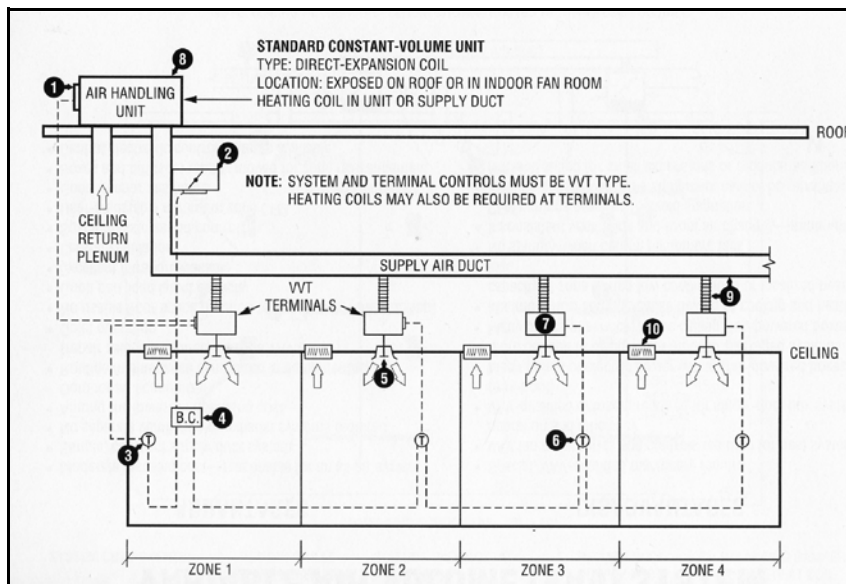
Rooftop Packaged Terminal AC (PTAC) - Food Store w/Suspended Ceiling  
(from The Trane Company "Systems Manual")



Rooftop VAV with Central Chiller/cooling Tower - Office w/Suspended Ceiling  
(from The Trane Company "Systems Manual")

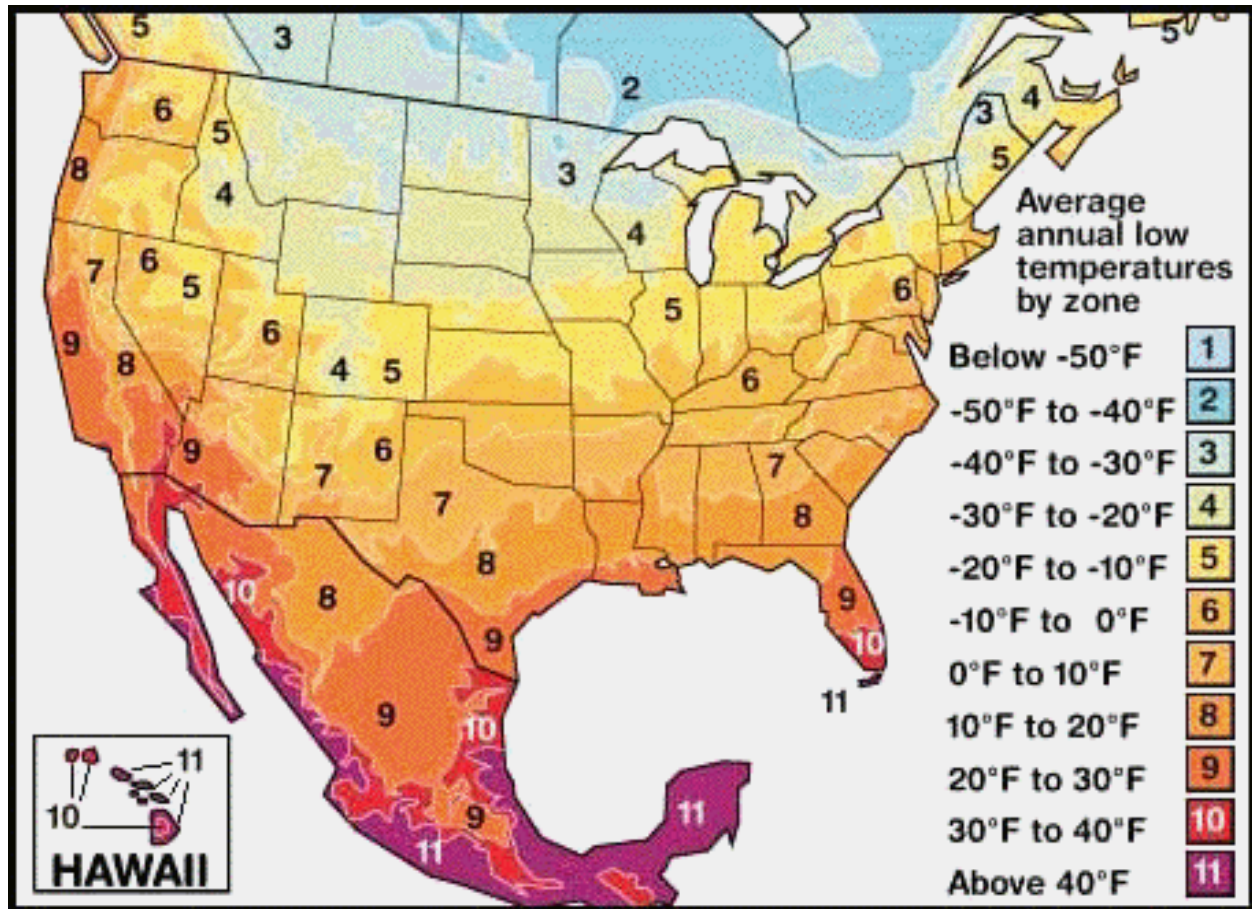


Rooftop Packaged Terminal AC (PTAC) - Office and Food Store Open Plenum w//Ducted Return (from Carrier Corporation "Commercial Systems Quick Reference")



Rooftop Air Handling Unit (AHU) with VAV Air Supply and Return Air Plenum - Office w/Suspended Ceiling (from Carrier Corporation "Commercial Systems Quick Reference")

## A2 Climate Zone Map of the United States



### A3 Office and Food Store Cost Estimates - Suspended Ceiling vs. Open Plenum

#### Office Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study

				CHICAGO			
				Suspended Ceiling		Open Plenum	
COST DATA				unit	total	unit	total
				cost	cost	cost	cost
<b>Suspended Ceiling</b>							
	Acoustic Tile - 3/4"	15000	S.F.	2.50	37,500.00		
	Suspension System, 2x2 grid	15000	S.F.	1.60	24,000.00		
	1 1/2" carrier channels	15000	S.F.	1.35	20,250.00		
	subtotal			5.45	81,750.00		
<b>Painting</b>							
	Paint Ceiling	15000	S.F.			0.93	13,950.00
	Paint Mechanical Systems	15000	S.F.			0.93	13,950.00
<b>HVAC</b>							
	Centrifugal fan (return/exhaust)	2	EA.			3,803.77	7,607.54
	Rectangular Duct - Supply	200	L.F.	162.20	32,440.00	162.20	32,440.00
	Rectangular Duct - Return	200	L.F.			162.20	32,440.00
	Stub Duct-Supply	16	L.F.			162.20	2,595.20
	Stub Duct-Return	16	L.F.			162.20	2,595.20
	Flex Duct - Supply, insulated	128	L.F.	17.26	2,209.28		
	Flex Duct-Return non-insulated	128	L.F.	13.82	1,768.96		
	Supply Diffuser						
	Return Grille						
	subtotal				36,418.24		77,677.94
<b>Electrical</b>							
	Power - MC Cable	4000	L.F.	3.59	14,372.00		
	Power - Conduit	4000	L.F.			7.67	30,680.00
	Cabletray	500	L.F.	29.15	14,575.00		
	subtotal				28,947.00		30,680.00
<b>Lighting</b>							
	Fluorescent 2x2, recess mounted in grid	44		195.78	8,614.32		
	Fluorescent troffer, air handling	44		202.43	8,906.92		
	Strip fixture w/pendant	88				215.07	18,926.16
	subtotal				17,521.24		18,926.16
	total				\$164,636.48		\$141,234.10
	% difference				116.6%		



**Office Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

		CHARLOTTE			
		Suspended Ceiling		Open Plenum	
		unit	total	unit	total
<b>COST DATA</b>	quantity unit	cost	cost	cost	cost
<b>Suspended Ceiling</b>					
	Acoustic Tile - 3/4"	15000 S.F.	1.88	28,200.00	
	Suspension System, 2x2 grid, fire rated	15000 S.F.	1.27	19,050.00	
	1 1/2" carrier channels	15000 S.F.			
	subtotal		3.15	47,250.00	
<b>Painting</b>					
	Paint Ceiling	15000 S.F.		0.80	12,000.00
	Paint Mechanical Systems	15000 S.F.		0.80	12,000.00
<b>HVAC</b>					
	Centrifugal fan (return/exhaust)	2 EA.		2,653.27	5,306.54
	Rectangular Duct - Supply	200 L.F.	70.60	14,120.00	70.60 14,120.00
	Rectangular Duct - Return	200 L.F.			70.60 14,120.00
	Stub Duct-Supply	16 L.F.			70.60 1,129.60
	Stub Duct-Return	16 L.F.			70.60 1,129.60
	Flex Duct - Supply, insulated	128 L.F.	10.11	1,294.08	
	Flex Duct-Return non-insulated	128 L.F.	7.79	997.12	
	Supply Diffuser				
	Return Grille				
	subtotal			16,411.20	35,805.74
<b>Electrical</b>					
	Power - MC Cable	4000 L.F.	2.13	8,532.40	
	Power - Conduit	4000 L.F.			4.65 18,600.00
	Cabletray	500 L.F.	22.09	11,045.00	
	subtotal			19,577.40	18,600.00
<b>Lighting</b>					
	Fluorescent 2x2, recess mounted in grid	44	128.46	5,652.24	
	Fluorescent troffer, air handling	44	144.46	6,356.24	
	Strip fixture w/pendant	88			150.73 13,264.24
	subtotal			12,008.48	13,264.24
	total			\$95,247.08	\$79,669.98
	% difference			119.6%	

Office Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study

					OKLAHOMA CITY					
					Suspended Ceiling		Open Plenum			
					unit	total	unit	total		
<b>COST DATA</b>					cost	cost	cost	cost		
	quantity	unit								
<b>Suspended Ceiling</b>										
	Acoustic Tile - 3/4"	15000 S.F.			1.79	26,850.00				
	Suspension System, 2x2 grid, fire rated 1 1/2" carrier channels	15000 S.F.			1.23	18,450.00				
	subtotal				3.02	45,300.00				
<b>Painting</b>										
	Paint Ceiling	15000 S.F.					0.50	7,500.00		
	Paint Mechanical Systems	15000 S.F.					0.50	7,500.00		
<b>HVAC</b>										
	Centrifugal fan (return/exhaust)	2 EA.					2,903.31	5,806.62		
	Rectangular Duct - Supply	200 L.F.			90.40	18,080.00	90.40	18,080.00		
	Rectangular Duct - Return	200 L.F.					90.40	18,080.00		
	Stub Duct-Supply	16 L.F.					90.40	1,446.40		
	Stub Duct-Return	16 L.F.					90.40	1,446.40		
	Flex Duct - Supply, insulated	128 L.F.			11.66	1,492.48				
	Flex Duct-Return non-insulated	128 L.F.			9.09	1,163.52				
	Supply Diffuser									
	Return Grille									
	subtotal					20,736.00		44,859.42		
<b>Electrical</b>										
	Power - MC Cable	4000 L.F.			2.35	9,406.00				
	Power - Conduit	4000 L.F.					5.10	20,400.00		
	Cabletray	500 L.F.			22.68	11,340.00				
	subtotal					20,746.00		20,400.00		
<b>Lighting</b>										
	Fluorescent 2x2, recess mounted in grid	44			137.87	6,066.28				
	Fluorescent troffer, air handling	44			151.81	6,679.64				
	Strip fixture w/pendant	88					159.10	14,000.80		
	subtotal					12,745.92		14,000.80		
	total					\$99,527.92		\$86,760.22		
	% difference							114.7%		

Office Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study

		ORLANDO				
		Suspended Ceiling		Open Plenum		
COST DATA	quantity	unit	unit cost	total cost	unit cost	total cost
<b>Suspended Ceiling</b>						
	Acoustic Tile - 3/4"	15000 S.F.	1.79	26,850.00		
	Suspension System, 2x2 grid, fire rated	15000 S.F.	1.39	20,850.00		
	1 1/2" carrier channels	15000 S.F.				
	subtotal			47,700.00		
<b>Painting</b>						
	Paint Ceiling	15000 S.F.			0.44	6,600.00
	Paint Mechanical Systems	15000 S.F.			0.44	6,600.00
<b>HVAC</b>						
	Centrifugal fan (return/exhaust)	2 EA.			2,889.68	5,779.36
	Rectangular Duct - Supply	200 L.F.	89.60	17,920.00	89.60	17,920.00
	Rectangular Duct - Return	200 L.F.			89.60	17,920.00
	Stub Duct-Supply	16 L.F.			89.60	1,433.60
	Stub Duct-Return	16 L.F.			89.60	1,433.60
	Flex Duct - Supply, insulated	128 L.F.	11.59	1,483.52		
	Flex Duct-Return non-insulated	128 L.F.	9.04	1,157.12		
	Supply Diffuser					
	Return Grille					
	subtotal			20,560.64		44,486.56
<b>Electrical</b>						
	Power - MC Cable	4000 L.F.	1.83	7,315.20		
	Power - Conduit	4000 L.F.			4.01	16,040.00
	Cabletray	500 L.F.	20.27	10,135.00		
	subtotal			17,450.20		16,040.00
<b>Lighting</b>						
	Fluorescent 2x2, recess mounted in grid	44	113.53	4,995.32		
	Fluorescent troffer, air handling	44	130.60	5,746.40		
	Strip fixture w/pendant	88			135.63	11,935.44
	subtotal			10,741.72		11,935.44
	total			\$96,452.56		\$79,062.00
	% difference			122.0%		

Office Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study

				PHOENIX			
				Suspended Ceiling		Open Plenum	
COST DATA				unit	total	unit	total
				cost	cost	cost	cost
<b>Suspended Ceiling</b>							
Acoustic Tile - 3/4"	15000	S.F.		2.06	30,900.00		
Suspension System, 2x2 grid, fire rated	15000	S.F.		1.30	19,500.00		
1 1/2" carrier channels	15000	S.F.					
	subtotal				50,400.00		
<b>Painting</b>							
Paint Ceiling	15000	S.F.				0.45	6,750.00
Paint Mechanical Systems	15000	S.F.				0.45	6,750.00
<b>HVAC</b>							
Centrifugal fan (return/exhaust)	2	EA.				3,091.17	6,182.34
Rectangular Duct - Supply	200	L.F.		105.20	21,040.00	105.20	21,040.00
Rectangular Duct - Return	200	L.F.				105.20	21,040.00
Stub Duct-Supply	16	L.F.				105.20	1,683.20
Stub Duct-Return	16	L.F.				105.20	1,683.20
Flex Duct - Supply, insulated	128	L.F.		12.82	1,640.96		
Flex Duct-Return non-insulated	128	L.F.		10.07	1,288.96		
Supply Diffuser							
Return Grille							
	subtotal				23,969.92		51,628.74
<b>Electrical</b>							
Power - MC Cable	4000	L.F.		2.35	9,389.60		
Power - Conduit	4000	L.F.				5.09	20,360.00
Cabletray	500	L.F.		23.14	11,570.00		
	subtotal				20,959.60		20,360.00
<b>Lighting</b>							
Fluorescent 2x2, recess mounted in grid	44			138.38	6,088.72		
Fluorescent troffer, air handling	44			153.04	6,733.76		
Strip fixture w/pendant	88					160.24	14,101.12
	subtotal				12,822.48		14,101.12
	total				\$108,152.00		\$92,839.86
	% difference				116.5%		

**Food Store Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

		CHICAGO				
		Suspended Ceiling		Open Plenum		
	quantity	unit	unit cost	total cost	unit cost	total cost
<b>COST DATA</b>						
<b>Suspended Ceiling</b>						
			2.50	25,000.00		
	10000	S.F.				
			1.29	12,900.00		
	10000	S.F.				
			1.35	13,500.00		
	10000	S.F.				
	subtotal		5.14	51,400.00		
<b>Painting</b>						
					0.93	9,300.00
	10000	S.F.				
					0.93	9,300.00
	10000	S.F.				
<b>HVAC</b>						
					3,803.77	7,607.54
	2	EA.				
			162.20	24,330.00	162.20	24,330.00
	150	L.F.				
					162.20	24,330.00
	150	L.F.				
					162.20	1,622.00
	10	L.F.				
					162.20	1,622.00
	10	L.F.				
			17.26	1,726.00		
	100	L.F.				
			13.82	1,382.00		
	100	L.F.				
			192.03	11,521.80		
	60	EA.				
	subtotal			38,959.80		59,511.54
<b>Electrical</b>						
			3.59	10,779.00		
	3000	L.F.				
					7.67	23,010.00
	3000	L.F.				
			29.15	0.00		
		L.F.				
	subtotal			10,779.00		23,010.00
<b>Lighting</b>						
			195.85	19,585.00		
	100					
					229.86	22,986.00
	100					
	subtotal			19,585.00		22,986.00
	total			\$120,723.80		\$114,807.54
	% difference					105.2%

**Food Store Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

					CHARLOTTE					
					Suspended Ceiling		Open Plenum			
					unit	total	unit	total		
<b>COST DATA</b>					cost	cost	cost	cost		
	quantity	unit								
<b>Suspended Ceiling</b>										
Acoustic Tile - 3/4"	10000	S.F.			1.88	18,800.00				
Suspension System, 2x2 grid, fire rated	10000	S.F.			1.03	10,300.00				
1 1/2" carrier channels w/recessed lighting	10000	S.F.								
	subtotal				2.91	29,100.00				
<b>Painting</b>										
Paint Ceiling	10000	S.F.					0.80	8,000.00		
Paint Mechanical Systems	10000	S.F.					0.80	8,000.00		
<b>HVAC</b>										
Centrifugal fan (return/exhaust)	2	EA.					2,653.27	5,306.54		
Rectangular Duct - Supply	150	L.F.			70.60	10,590.00	70.60	10,590.00		
Rectangular Duct - Return	150	L.F.					70.60	10,590.00		
Stub Duct-Supply	10	L.F.					70.60	706.00		
Stub Duct-Return	10	L.F.					70.60	706.00		
Flex Duct - Supply, insulated	100	L.F.			10.11	1,011.00				
Flex Duct-Return non-insulated	100	L.F.			7.79	779.00				
SupplyReturn Diffuser/Register	60	EA.			160.52	9,631.20				
	subtotal						22,011.20	27,898.54		
<b>Electrical</b>										
Power - MC Cable	3000	L.F.			2.13	6,399.30				
Power - Conduit	3000	L.F.					4.65	13,950.00		
Cabletray		L.F.			22.09	0.00				
	subtotal						6,399.30	13,950.00		
<b>Lighting</b>										
H.I.D. Recessed	100				152.69	15,269.00				
H.I.D. w/pendant	100						176.44	17,644.00		
	subtotal						15,269.00	17,644.00		
	total						\$72,779.50	\$67,492.54		
	% difference						107.8%			

**Food Store Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

		OKLAHOMA CITY			
		Suspended Ceiling		Open Plenum	
		unit	total	unit	total
<b>COST DATA</b>	quantity	cost	cost	cost	cost
	unit				
<b>Suspended Ceiling</b>					
Acoustic Tile - 3/4"	10000 S.F.	1.79	17,900.00		
Suspension System, 2x2 grid, fire rated	10000 S.F.	0.99	9,900.00		
1 1/2" carrier channels	10000 S.F.				
w/recessed lighting	S.F.				
	subtotal	2.78	27,800.00		
<b>Painting</b>					
Paint Ceiling	10000 S.F.			0.50	5,000.00
Paint Mechanical Systems	10000 S.F.			0.50	5,000.00
<b>HVAC</b>					
Centrifugal fan (return/exhaust)	2 EA.			2,903.31	5,806.62
Rectangular Duct - Supply	150 L.F.	90.40	13,560.00	90.40	13,560.00
Rectangular Duct - Return	150 L.F.			90.40	13,560.00
Stub Duct-Supply	10 L.F.			90.40	904.00
Stub Duct-Return	10 L.F.			90.40	904.00
Flex Duct - Supply, insulated	100 L.F.	11.66	1,166.00		
Flex Duct-Return non-insulated	100 L.F.	9.09	909.00		
SupplyReturn Diffuser/Register	60 EA.	167.41	10,044.60		
	subtotal		25,679.60		34,734.62
<b>Electrical</b>					
Power - MC Cable	3000 L.F.	2.35	7,054.50		
Power - Conduit	3000 L.F.			5.10	15,300.00
Cabletray	L.F.	22.68	0.00		
	subtotal		7,054.50		15,300.00
<b>Lighting</b>					
H.I.D. Recessed	100	157.16	15,716.00		
H.I.D. w/pendant	100			182.24	18,224.00
	subtotal		15,716.00		18,224.00
	total		\$76,250.10		\$73,258.62
	% difference		104.1%		

**Food Store Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

				ORLANDO			
				Suspended Ceiling		Open Plenum	
COST DATA				unit	total	unit	total
				cost	cost	cost	cost
<b>Suspended Ceiling</b>							
	Acoustic Tile - 3/4"	10000 S.F.		1.79	17,900.00		
	Suspension System, 2x2 grid, fire rated	10000 S.F.		1.12	11,200.00		
	1 1/2" carrier channels	10000 S.F.					
	w/recessed lighting	S.F.					
	subtotal				29,100.00		
<b>Painting</b>							
	Paint Ceiling	10000 S.F.				0.44	4,400.00
	Paint Mechanical Systems	10000 S.F.				0.44	4,400.00
<b>HVAC</b>							
	Centrifugal fan (return/exhaust)	2 EA.				2,889.68	5,779.36
	Rectangular Duct - Supply	150 L.F.		89.60	13,440.00	89.60	13,440.00
	Rectangular Duct - Return	150 L.F.				89.60	13,440.00
	Stub Duct-Supply	10 L.F.				89.60	896.00
	Stub Duct-Return	10 L.F.				89.60	896.00
	Flex Duct - Supply, insulated	100 L.F.		11.59	1,159.00		
	Flex Duct-Return non-insulated	100 L.F.		9.04	904.00		
	SupplyReturn Diffuser/Register	60 EA.		166.86	10,011.60		
	subtotal				25,514.60		34,451.36
<b>Electrical</b>							
	Power - MC Cable	3000 L.F.		1.83	5,486.40		
	Power - Conduit	3000 L.F.				4.01	12,030.00
	Cabletray	L.F.		20.27	0.00		
	subtotal				5,486.40		12,030.00
<b>Lighting</b>							
	H.I.D. Recessed	100		141.03	14,103.00		
	H.I.D. w/pendant	100				162.37	16,237.00
	subtotal				14,103.00		16,237.00
	total				\$74,204.00		\$67,118.36
	% difference				110.6%		



**Food Store Building - Suspended Ceilings vs. Open Plenum - Life Cycle Study**

		PHOENIX				
		Suspended Ceiling		Open Plenum		
	quantity	unit	unit cost	total cost	unit cost	total cost
<b>COST DATA</b>						
<b>Suspended Ceiling</b>						
	Acoustic Tile - 3/4"	10000 S.F.	2.06	20,600.00		
	Suspension System, 2x2 grid, fire rated	10000 S.F.	1.05	10,500.00		
	1 1/2" carrier channels	10000 S.F.				
	w/recessed lighting	S.F.				
	subtotal			31,100.00		
<b>Painting</b>						
	Paint Ceiling	10000 S.F.			0.45	4,500.00
	Paint Mechanical Systems	10000 S.F.			0.45	4,500.00
<b>HVAC</b>						
	Centrifugal fan (return/exhaust)	2 EA.			3,091.17	6,182.34
	Rectangular Duct - Supply	150 L.F.	105.20	15,780.00	105.20	15,780.00
	Rectangular Duct - Return	150 L.F.			105.20	15,780.00
	Stub Duct-Supply	10 L.F.			105.20	1,052.00
	Stub Duct-Return	10 L.F.			105.20	1,052.00
	Flex Duct - Supply, insulated	100 L.F.	12.82	1,282.00		
	Flex Duct-Return non-insulated	100 L.F.	10.07	1,007.00		
	SupplyReturn Diffuser/Register	60 EA.	172.67	10,360.20		
	subtotal			28,429.20		39,846.34
<b>Electrical</b>						
	Power - MC Cable	3000 L.F.	2.35	7,042.20		
	Power - Conduit	3000 L.F.			5.09	15,270.00
	Cabletray	L.F.	23.14	0.00		
	subtotal			7,042.20		15,270.00
<b>Lighting</b>						
	H.I.D. Recessed	100	159.13	15,913.00		
	H.I.D. w/pendant	100			184.39	18,439.00
	subtotal			15,913.00		18,439.00
	total			\$82,484.40		\$78,055.34
	% difference			105.7%		

A4 Energy / Cost Analyses of Office and Food Store - Suspended Ceiling vs. Open Plenum

**CISCA Office**  
**Chicago Midway Airport, IL**  
**BDA**  
**Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Single Stage Centrifugal	Single Stage Centrifugal
Floor Area	7+ Story Office	7+ Story Office
Max Building Cooling Load	120,000 ft2	120,000 ft2
Max Building Heating Load	282 tons	292 tons
System Set 1	2,687 mbh	2,703 mbh
Cooling Plant 1	FPVAV - Parallel (118,230 cfm)	FPVAV - Parallel (122,742 cfm)
Heating Plant	Single Stage Centrifugal (282 tons)	Single Stage Centrifugal (292 tons)
Building Cooling Coil load	Gas Fired Boiler (2,687 mbh)	Gas Fired Boiler (2,703 mbh)
Building Heating Coil load	199,043 ton-hrs/year	211,544 ton-hrs/year
Building Energy Usage	1,103,933 kBtu/year	1,065,105 kBtu/year
Building Energy (Utility) Cost	52,563 Btu/(ft2-year)	55,175 Btu/(ft2-year)
	1.418 \$/(ft2-year)	1.530 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	283.2%
Life Cycle Cost Difference	\$74,393
Net Present Value of Cash Flows	\$74,393
Life Cycle payback on Investment	0.4 yrs
Simple Payback on investment	0.3 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-190,277 lbm/year
SO2 Impact ( - denotes Reduction)	-1,139,580 gm/year
NOX Impact ( - denotes reduction)	-380,225 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Chicago Midway Airport, IL	Chicago Midway Airpo
Building Area	120,000 ft2	120,000 ft2
Weekly Operating Hours	58	58
Number of Occupants	600	600
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	1,311,120 kWh	1,420,697 kWh
Annual Gas Consumption	18,327 therms	17,722 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

Energy Star Building Label website: [www.epa.gov/buildinglabel](http://www.epa.gov/buildinglabel)

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**CISCA Office  
 Charlotte, NC  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Single Stage Centrifugal	Single Stage Centrifugal
Floor Area	7+ Story Office	7+ Story Office
Max Building Cooling Load	120,000 ft2	120,000 ft2
Max Building Heating Load	289 tons	299 tons
System Set 1	2,001 mbh	2,018 mbh
Cooling Plant 1	FPVAV - Parallel (120,254 cfm)	FPVAV - Parallel (124,788 cfm)
Heating Plant	Single Stage Centrifugal (289 tons)	Single Stage Centrifugal (299 tons)
Building Cooling Coil load	Gas Fired Boiler (2,001 mbh)	Gas Fired Boiler (2,018 mbh)
Building Heating Coil load	253,409 ton-hrs/year	270,668 ton-hrs/year
Building Energy Usage	585,086 kBtu/year	576,745 kBtu/year
Building Energy (Utility) Cost	47,482 Btu/(ft2-year)	50,664 Btu/(ft2-year)
	1.883 \$/(ft2-year)	2.032 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	<= 0
Life Cycle Cost Difference	\$98,596
Net Present Value of Cash Flows	\$98,596
Life Cycle payback on Investment	0.3 yrs
Simple Payback on Investment	0.3 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-172,459 lbm/year
SO2 Impact ( - denotes Reduction)	-800,849 gm/year
NOX Impact ( - denotes reduction)	-289,389 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Charlotte, NC	Charlotte, NC
Building Area	120,000 ft2	120,000 ft2
Weekly Operating Hours	58	58
Number of Occupants	600	600
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	1,364,524 kWh	1,480,590 kWh
Annual Gas Consumption	10,407 therms	10,264 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

Energy Star Building Label website: [www.epa.gov/buildinglabel](http://www.epa.gov/buildinglabel)

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**CISCA Office  
 OK City, OK  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Single Stage Centrifugal	Single Stage Centrifugal
Floor Area	7+ Story Office	7+ Story Office
Max Building Cooling Load	120,000 ft2	120,000 ft2
Max Building Heating Load	295 tons	305 tons
System Set 1	2,271 mbh	2,288 mbh
Cooling Plant 1	FPVAV - Parallel (125,793 cfm)	FPVAV - Parallel (130,424 cfm)
Heating Plant	Single Stage Centrifugal (295 tons)	Single Stage Centrifugal (306 tons)
Building Cooling Coil load	Gas Fired Boiler (2,271 mbh)	Gas Fired Boiler (2,288 mbh)
Building Heating Coil load	274,707 ton-hrs/year	291,047 ton-hrs/year
Building Energy Usage	629,349 kBtu/year	612,152 kBtu/year
Building Energy (Utility) Cost	48,697 Btu/(ft2-year)	51,724 Btu/(ft2-year)
	0.491 \$/(ft2-year)	0.525 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	129.4%
Life Cycle Cost Difference	\$23,498
Net Present Value of Cash Flows	\$23,498
Life Cycle payback on Investment	0.9 yrs
Simple Payback on Investment	0.7 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-190,643 lbm/year
SO2 Impact ( - denotes Reduction)	-250,469 gm/year
NOX Impact ( - denotes reduction)	-283,257 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	OK City, OK	OK City, OK
Building Area	120,000 ft2	120,000 ft2
Weekly Operating Hours	58	58
Number of Occupants	600	600
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	1,386,956 kWh	1,500,808 kWh
Annual Gas Consumption	11,099 therms	10,847 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

Energy Star Building Label website: [www.epa.gov/buildinglabel](http://www.epa.gov/buildinglabel)

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**CISCA Office  
 Orlando, FL  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Single Stage Centrifugal	Single Stage Centrifugal
Floor Area	7+ Story Office	7+ Story Office
Max Building Cooling Load	120,000 ft2	120,000 ft2
Max Building Heating Load	294 tons	305 tons
System Set 1	1,511 mbh	1,528 mbh
Cooling Plant 1	FPVAV - Parallel (115,920 cfm)	FPVAV - Parallel (120,343 cfm)
Heating Plant	Single Stage Centrifugal (294 tons)	Single Stage Centrifugal (305 tons)
Building Cooling Coil load	Gas Fired Boiler (1,511 mbh)	Gas Fired Boiler (1,528 mbh)
Building Heating Coil load	481,740 ton-hrs/year	511,470 ton-hrs/year
Building Energy Usage	139,304 kBtu/year	135,852 kBtu/year
Building Energy (Utility) Cost	48,225 Btu/(ft2-year)	51,668 Btu/(ft2-year)
	1.781 \$/(ft2-year)	1.916 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	184.9%
Life Cycle Cost Difference	\$86,669
Net Present Value of Cash Flows	\$86,669
Life Cycle payback on Investment	0.6 yrs
Simple Payback on Investment	0.5 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-183,791 lbm/year
SO2 Impact ( - denotes Reduction)	-849,030 gm/year
NOX Impact ( - denotes reduction)	-307,251 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Orlando, FL	Orlando, FL
Building Area	120,000 ft2	120,000 ft2
Weekly Operating Hours	58	58
Number of Occupants	600	600
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	1,562,910 kWh	1,685,959 kWh
Annual Gas Consumption	4,528 therms	4,460 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

Energy Star Building Label website: [www.epa.gov/buildinglabel](http://www.epa.gov/buildinglabel)

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**CISCA Office  
 Phoenix, AZ  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Single Stage Centrifugal	Single Stage Centrifugal
Floor Area	7+ Story Office	7+ Story Office
Max Building Cooling Load	120,000 ft2	120,000 ft2
Max Building Heating Load	298 tons	308 tons
System Set 1	1,661 mbh	1,678 mbh
Cooling Plant 1	FPVAV - Parallel (133,986 cfm)	FPVAV - Parallel (138,587 cfm)
Heating Plant	Single Stage Centrifugal (298 tons)	Single Stage Centrifugal (308 tons)
Building Cooling Coil load	Gas Fired Boiler (1,661 mbh)	Gas Fired Boiler (1,678 mbh)
Building Heating Coil load	335,719 ton-hrs/year	353,213 ton-hrs/year
Building Energy Usage	414,545 kBtu/year	411,690 kBtu/year
Building Energy (Utility) Cost	48,352 Btu/(ft2-year)	51,606 Btu/(ft2-year)
	0.902 \$/(ft2-year)	0.970 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	<= 0
Life Cycle Cost Difference	\$47,846
Net Present Value of Cash Flows	\$47,846
Life Cycle payback on Investment	0.1 yrs
Simple Payback on investment	0.1 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-115,040 lbm/year
SO2 Impact ( - denotes Reduction)	-126,990 gm/year
NOX Impact ( - denotes reduction)	-172,978 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Phoenix, AZ	Phoenix, AZ
Building Area	120,000 ft2	120,000 ft2
Weekly Operating Hours	58	58
Number of Occupants	600	600
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	1,460,995 kWh	1,576,441 kWh
Annual Gas Consumption	8,158 therms	8,123 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

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**CISCA Food Store  
 Chicago Midway Airport, IL  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Small Foodl-Susp Clg CHICAGO	Small Food-Open Plenum
Floor Area	Large Retail	Large Retail
Max Building Cooling Load	10,000 ft2	10,000 ft2
Max Building Heating Load	37 tons	39 tons
System Set 1	435 mbh	441 mbh
Cooling Plant 1	Pkgd. Terminal A/C (15,443 cfm)	Variable Temp CV (16,219 cfm)
Heating Plant	Small Commercial (37 tons)	Small Commercial (39 tons)
Building Cooling Coil load	Gas Fired Rooftop (435 mbh)	Gas Fired Rooftop (442 mbh)
Building Heating Coil load	38,313 ton-hrs/year	41,353 ton-hrs/year
Building Energy Usage	348,285 kBtu/year	320,281 kBtu/year
Building Energy (Utility) Cost	106,281 Btu/(ft2-year)	116,506 Btu/(ft2-year)
	2.337 \$/(ft2-year)	2.809 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	84.3%
Life Cycle Cost Difference	\$22,560
Net Present Value of Cash Flows	\$22,560
Life Cycle payback on Investment	1.4 yrs
Simple Payback on Investment	1.1 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-68,363 lbm/year
SO2 Impact ( - denotes Reduction)	-418,233 gm/year
NOX Impact ( - denotes reduction)	-138,851 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Chicago Midway Airport, IL	Chicago Midway Airpo
Building Area	10,000 ft2	10,000 ft2
Weekly Operating Hours	98	98
Number of Occupants	50	50
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	183,842 kWh	224,058 kWh
Annual Gas Consumption	4,354 therms	4,004 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

Energy Star Building Label website: [www.epa.gov/buildinglabel](http://www.epa.gov/buildinglabel)

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**CISCA Food Store  
 Charlotte, NC  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Small Foodl-Susp Clg	Small Food-Open Plenum
Floor Area	Large Retail	Large Retail
Max Building Cooling Load	10,000 ft2	10,000 ft2
Max Building Heating Load	40 tons	41 tons
System Set 1	294 mbh	298 mbh
Cooling Plant 1	Pkgd. Terminal A/C (16,319 cfm)	Variable Temp CV (17,101 cfm)
Heating Plant	Small Commercial (40 tons)	Small Commercial (41 tons)
Building Cooling Coil load	Gas Fired Rooftop (294 mbh)	Gas Fired Rooftop (298 mbh)
Building Heating Coil load	51,759 ton-hrs/year	55,570 ton-hrs/year
Building Energy Usage	116,681 kBtu/year	107,403 kBtu/year
Building Energy (Utility) Cost	82,775 Btu/(ft2-year)	96,468 Btu/(ft2-year)
	2.690 \$/(ft2-year)	3.276 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	140.6%
Life Cycle Cost Difference	\$30,093
Net Present Value of Cash Flows	\$30,093
Life Cycle payback on Investment	0.8 yrs
Simple Payback on Investment	0.6 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-63,950 lbm/year
SO2 Impact ( - denotes Reduction)	-300,309 gm/year
NOX Impact ( - denotes reduction)	-108,177 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Charlotte, NC	Charlotte, NC
Building Area	10,000 ft2	10,000 ft2
Weekly Operating Hours	98	98
Number of Occupants	50	50
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	199,790 kWh	243,314 kWh
Annual Gas Consumption	1,459 therms	1,343 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

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**CISCA Food Store  
 OK City, OK  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

	Alternative 1	Alternative 2
Alternative Description	Small Food-Susp Clg	Small Food-Open Plenum
Building Name	Large Retail	Large Retail
Floor Area	10,000 ft2	10,000 ft2
Max Building Cooling Load	41 tons	42 tons
Max Building Heating Load	347 mbh	352 mbh
System Set 1	Pkgd. Terminal A/C (17,229 cfm)	Variable Temp CV (18,035 cfm)
Cooling Plant 1	Small Commercial (41 tons)	Small Commercial (42 tons)
Heating Plant	Gas Fired Rooftop (347 mbh)	Gas Fired Rooftop (352 mbh)
Building Cooling Coil load	58,363 ton-hrs/year	62,339 ton-hrs/year
Building Heating Coil load	146,973 kBtu/year	132,506 kBtu/year
Building Energy Usage	91,119 Btu/(ft2-year)	102,895 Btu/(ft2-year)
Building Energy (Utility) Cost	2.047 \$/(ft2-year)	2.378 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	135.8%
Life Cycle Cost Difference	\$17,175
Net Present Value of Cash Flows	\$17,175
Life Cycle payback on Investment	0.8 yrs
Simple Payback on Investment	0.6 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-65,578 lbm/year
SO2 Impact ( - denotes Reduction)	-87,550 gm/year
NOX Impact ( - denotes reduction)	-98,512 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	OK City, OK	OK City, OK
Building Area	10,000 ft2	10,000 ft2
Weekly Operating Hours	98	98
Number of Occupants	50	50
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	213,153 kWh	252,951 kWh
Annual Gas Consumption	1,837 therms	1,656 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

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**CISCA Food Store  
 Orlando, FL  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Small Foodl-Susp Clg	Small Food-Open Plenum
Floor Area	Large Retail	Large Retail
Max Building Cooling Load	10,000 ft2	10,000 ft2
Max Building Heating Load	41 tons	43 tons
System Set 1	194 mbh	197 mbh
Cooling Plant 1	Pkgd. Terminal A/C (15,794 cfm)	Variable Temp CV (16,558 cfm)
Heating Plant	Small Commercial (41 tons)	Small Commercial (43 tons)
Building Cooling Coil load	Gas Fired Rooftop (194 mbh)	Gas Fired Rooftop (197 mbh)
Building Heating Coil load	100,704 ton-hrs/year	108,534 ton-hrs/year
Building Energy Usage	14,252 kBtu/year	13,695 kBtu/year
Building Energy (Utility) Cost	89,117 Btu/(ft2-year)	105,256 Btu/(ft2-year)
	2.923 \$/(ft2-year)	3.422 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	73.0%
Life Cycle Cost Difference	\$23,074
Net Present Value of Cash Flows	\$23,074
Life Cycle payback on Investment	1.6 yrs
Simple Payback on Investment	1.2 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-71,151 lbm/year
SO2 Impact ( - denotes Reduction)	-327,663 gm/year
NOX Impact ( - denotes reduction)	-118,681 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Orlando, FL	Orlando, FL
Building Area	10,000 ft2	10,000 ft2
Weekly Operating Hours	98	98
Number of Occupants	50	50
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	255,893 kWh	303,380 kWh
Annual Gas Consumption	178 therms	171 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

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**CISCA Food Store  
 Phoenix, AZ  
 BDA  
 Barry Donaldson**

BUILDING DESCRIPTION

Alternative Description	Alternative 1	Alternative 2
Building Name	Small Food-Susp Clg	Small Food-Open Plenum
Floor Area	Large Retail	Large Retail
Max Building Cooling Load	10,000 ft2	10,000 ft2
Max Building Heating Load	41 tons	42 tons
System Set 1	215 mbh	218 mbh
Cooling Plant 1	Pkgd. Terminal A/C (19,233 cfm)	Variable Temp CV (20,054 cfm)
Heating Plant	Small Commercial (41 tons)	Small Commercial (42 tons)
Building Cooling Coil load	Gas Fired Rooftop (215 mbh)	Gas Fired Rooftop (218 mbh)
Building Heating Coil load	65,368 ton-hrs/year	69,844 ton-hrs/year
Building Energy Usage	68,030 kBtu/year	64,871 kBtu/year
Building Energy (Utility) Cost	87,842 Btu/(ft2-year)	101,578 Btu/(ft2-year)
	1.604 \$/(ft2-year)	1.881 \$/(ft2-year)

LIFE CYCLE COST ANALYSIS

	Alt 1 - 2
Internal Rate of Return	79.6%
Life Cycle Cost Difference	\$13,250
Net Present Value of Cash Flows	\$13,250
Life Cycle payback on Investment	1.5 yrs
Simple Payback on Investment	1.1 yrs

ENVIRONMENTAL IMPACT ANALYSIS

	Alt 1 - 2
CO2 Impact ( - denotes Reduction)	-40,948 lbm/year
SO2 Impact ( - denotes Reduction)	-45,540 gm/year
NOX Impact ( - denotes reduction)	-61,887 gm/year

INPUTS TO ENERGY STAR BUILDING LABEL BENCHMARKING TOOL

Alternative	1	2
City	Phoenix, AZ	Phoenix, AZ
Building Area	10,000 ft2	10,000 ft2
Weekly Operating Hours	98	98
Number of Occupants	50	50
Number of PC's Per Occupant	User Defined	User Defined
Annual Electric Consumption	232,462 kWh	273,863 kWh
Annual Gas Consumption	850 therms	811 therms
Annual Oil Consumption	0 therms	0 therms
Annual Steam Consumption	0 therms	0 therms

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