REPORT

pertaining to

ST. AGNES ELEMENTARY SCHOOL

AIR CONDITIONING AND

ENERGY SAVINGS ANALYSIS

provided for

St. Agnes Elementary School
Fort Wright, KY

prepared by

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Project #11013.01

May 15, 2008

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I. BACKGROUND

This report summarizes the findings of an energy-cost-reduction and air-conditioning feasibility study performed for St. Agnes Elementary School. The ThermalTech team conducted the study to identify as many practical energy efficiency improvements as possible and to determine the best way to provide cooling for the students.

For the energy study, the team interviewed plant personnel, conducted a site survey, and analyzed historical energy consumption data to develop a list of energy savings projects. The capital cost and the energy savings were estimated for some of the opportunities. Note that the study was intended to be a low-cost screening method, not a rigorous and detailed analysis. Further analysis and investigation may be appropriate in some cases before implementing or rejecting an opportunity.

For the air-conditioning study, cooling and ventilation loads were estimated, alternative concepts were developed, and several factors were evaluated for each alternative (construction cost, operating cost, noise, maintenance) to determine the best system. More detailed cost estimates were then performed for the best alternatives.

St. Agnes Elementary School is a private school for 450 students located in Covington, Kentucky. The school consists of the 37,000 SF original building constructed in the mid-50s and a 17,000 SF addition built in the mid-80s. Electricity and natural gas are provided by Duke Energy.

Electric energy consumption at the facility for calendar year 2007 was 393,000 kWH with a peak demand of 116 kW and an annual cost of $27,000. Natural gas consumption for the calendar year 2007 was 1,656 MCF and an annual cost of about $21,000. Therefore, the total annual electric and gas costs are about $48,000 or a little less than $0.90/SF.

II. SUMMARY AND RECOMMENDATIONS

Table 1 summarizes the economics for the opportunities that are recommended for implementation or further evaluation. The ECMs that are included in Table 1 are those that have a "1" in the "Recommended" column of the Table 2 ECM Screening Tool. These ECMs have a potential annual savings of about $15,000, representing a cost savings of approximately 30%. This savings would offset about 50-100% of the cost of air conditioning the building. The major savings areas are in unoccupied-cycle controls.

Table 2 lists all of the potential Energy Conservation Measures (ECMs) that were identified. The preliminary savings and cost estimates are shown, along with energy quantities, CO2 savings, simple payback, and annual rate-of-return. See Section III for a further explanation of the assumptions.

Several candidate air conditioning system alternatives were analyzed to meet the objectives of the project. These alternatives included unitary cooling equipment, a central chiller with fan coil units, and the use of a DOAS (dedicated outdoor air system). The alternatives are discussed in Section III.

Due to the potential problems with poor humidity control and mold/mildew growth, we recommend that a DOAS be used with one of the terminal systems. Although this increases the first cost, the concepts that rely on operable windows are more likely to have comfort or health issues.

We recommend either Alternative #2a (DOAS with split systems) or Alternative #5b (DOAS with central chiller and full thermal storage) as the concepts that are in the best interest of the school. There is some potential to use Alternative #5b as a visible student educational tool.

St. Agnes Elementary School
ThermalTech Engineering
Energy Conservation Measure Screening Tool

5/1/2008

Table 1 Recommended Energy Conservation Measures

The table includes all ECMs that are flagged as recommended in Table 2 with a criteria that matches that which is shown below.

Rec'd ECMs	1		**Annual After-Tax Rate-of-Return**
Plant or Bldg	Data	Total	
SAES	Estimated Annual Util Savings	$15,220	
	Other Annual Savings (e.g. Maint)		
	Bare Installed Cost	$24,001	
	Avoided Costs	$800	
	Installed Cost Less Avoided Cost	$23,101	
	Annual kWH Saved	$63,713	
	Annual kW Saved	$89	
	Annual mmBTU Gas Saved	$847	
	Annual CO2e Reduction (tons)	$113	
	Simple Payback Period, Years	$2	70%

The total capital cost required to implement all items equals the "Total Installed Cost Less Avoided Cost" plus the "Total Avoided Cost".

St. Agnes Elementary School

ThermalTech Engineering -- Energy Conservation Measure Screening Tool

Table 2 Energy Conservation Measure Opportunities

5/1/2008

Plant or Bldg	ECM #	Energy Theme	Description	Estimated Annual Util Savings	Other Annual Savings (e.g. Maint)	Avoided Costs	Total Installation Cost Less Avoided Cost	Simple Payback (yrs)	IRR, % per Yr RUN MACRO	Installed Cost Per Ton CO2e Saved per Year	Annual kWH Saved	Annual kW Saved	Annual mmBTU Gas Saved	Annual CO2e Reduct (tons)	Comments	Rec'd ECMs
SAES	1	ENV	Provide weatherstripping seals on the entrance doors on the east side of the building.	$0							0	0	0	0		1
SAES	2	HVAC	Install a stand-alone dehumidifier in the gym in lieu of running the 40-ton condensing unit during unoccupied times. Allow the space temperature to rise but keep the relative humidity low enough to prevent floor buckling. Alternately, modify the existing condensing unit and AHU to run at the lowest possible load for moisture removal only.	$2,300			$5,000	2.2	50%	$148	33,869	50	0	34	cost is a guess	1
SAES	3	HVAC	Replace the deteriorated AC unit for the library as part of the building AC project. The free cooling system on this unit does not work.	$0							0	0	0	0		1
SAES	4	HVAC	Turn off the exhaust fans in the addition during unoccupied periods. These serve various classrooms and run continuously, causing energy waste and potential for freezing unit ventilator coils. They should only be run during times when free cooling is being done.	$2,500			$3,000	1.2	87%	$258	0	0	199	12	tie fans into DDC system	1
SAES	5	HVAC	Rework the exhaust fan that serves the computer lab or install a louver in the storage room wall. The air is all pulled from the storage room rather than the computer room.	$0							0	0	0	0		1
SAES	6	HVAC	Reset the boiler water temperature to a lower value during unoccupied periods so that setback can occur with less risk of freezing a coil.	$6,100			$2,000	0.3	309%	$72	0	0	475	28		1
SAES	7	HVAC	Provide unoccupied setback controls on the two office PTAC units and the office AC unit.	$300			$1,500	5.0	22%	$330	4,550	0	0	5		1
SAES	8	HVAC	Provide unoccupied setback controls on the gym HVAC unit.	$2,500			$2,000	0.8	129%	$93	13,410	0	137	21	this is after the dehumidification mods are made	1

Plant or Bldg	ECM #	Energy Theme	Description	Estimated Annual Util Savings	Other Annual Savings (e.g. Maint)	Avoided Costs	Total Installation Cost Less Avoided Cost	Simple Payback (yrs)	IRR, % per Yr RUN MACRO	Installed Cost Per Ton CO2e Saved per Year	Annual kWH Saved	Annual kW Saved	Annual mmBTU Gas Saved	Annual CO2e Reduct (tons)	Comments	Rec'd ECMs
SAES	9	HVAC	Use a blower to deliver combustion air to the boiler room only when a boiler is firing in lieu of the existing wide-open louvers.	$0							0	0	0	0	not likely cost effective	
SAES	10	HVAC	Insulate all bare hot water and domestic water pipe surfaces in the boiler room. Insulate the stacks on the water heaters since they will be operating when the building is air conditioned. This work could be done by volunteers or the in-house staff.	$300			$1,500	5.0	22%	$1,071	0	0	24	1		1
SAES	11	HVAC	Modify the digital control system to stage each boiler. It appears that the control system is just cycling the boiler to achieve the desired water temperature and the local boiler controls may not be using the low-fire stage.	$0			$400				0	0	0	0		1
SAES	12	HVAC	Replace all boilers with high-efficiency condensing types in lieu of the natural-draft, two-stage boilers.	$0							0	0	0	0	This is not practical since the two boilers for the original building were just recently replaced.	
SAES	13	HVAC	Modify the controls on the computer lab AC unit so that heating and cooling do not fight each other.	$0							0	0	0	0		1
SAES	14	LTG	Replace HID lighting in gym with T5 fluorescent with built-in occupancy sensors. The lighting level would be similar but lights would automatically turn off when there is no activity.	$800		$800	$7,200	9.0	12%	$833	8,640	35	0	9	Rebate is shown as avoided cost	1
SAES	15	LTG	Install occupancy sensors in the bathrooms, offices, break rooms, classrooms.	$0							0	0	0	0		1
SAES	16	LTG	Install daylight sensors in the main corridors to control the lighting.	$0							0	0	0	0	may not be enough natural light	
SAES	17	LTG	Replace the incandescent lamps shining on the statue by the entrance door with compact fluorescent lamps.	$0							0	0	0	0		1
SAES	18	LTG	Repair photocell on outdoor light on west side of building (light is on during daylight hours).	$60												1
SAES	19	POW	Replace all remaining CRT computer screens in the computer lab with LCD screens. Replace PCs or implement the sleep mode on PCs that run continuously.	$0							0	0	0	0		1

Plant or Bldg	ECM #	Energy Theme	Description	Estimated Annual Util Savings	Other Annual Savings (e.g. Maint)	Avoided Costs	Total Installation Cost Less Avoided Cost	Simple Payback (yrs)	IRR, % per Yr RUN MACRO	Installed Cost Per Ton CO2e Saved per Year	Annual kWH Saved	Annual kW Saved	Annual mmBTU Gas Saved	Annual CO2e Reduct (tons)	Comments	Rec'd ECMs
SAES	20	POW	Conduct training sessions, post signs about turning off classroom equipment during unoccupied periods (PCs, overhead projectors, ceiling fans, floor fans, TVs).	$0							0	0	0	0		1
SAES	21	WAT	Turn off the (3) ~1/4 HP domestic water circ pumps during unoccupied periods to reduce the heater usage. Disable the water heaters at the same time.	$300			$500	1.7	63%	$145	2,794	0	11	3	This could be done by the DDC system	1
SAES	22	WAT	Eliminate use of the electric water cooler compressors (unplug the units).	$60			$1	0.0	6000%	$2	450	4	0	0		1
Totals				**$15,220**	**$0**	**$800**	**$23,101**	**1.5**	**70%**	**$204**	**63,713**	**89**	**847**	**113**		

St. Agnes Elementary School

Table 3 Summary of Marginal Utility Rates, Greenhouse Gas Factors, and Present Energy Consumption

These rates are used to compute the Energy Conservation Measure savings in Table 2:

	Projected Rates Used in Table				Present Rates			GHG Factors			BASELINE CONSUMPTION			
Building	**$/kWh [1]**	**$/kW [1]**	**Demand Months**	**$/MMBTU [1]**	**$/kWh**	**$/kW**	**$/MMBTU**	**Electric, MT CO2e/ MWH [2]**	**Electric, # CO2e/ kWH**	**Gas, # CO2e/ MMBTU [2]**	**Annual kWH Used**	**Summer Peak Elect Demand, kW**	**Annual MMBTU Gas Used**	**Annual CO2e Emitted (tons) [2]**
SAES	$0.0554	$8.78	12	$12.74	$0.0503	$7.98	$12.13	0.907	2.000	116.7	393,000	117	1,706	493
Average	$0.0554	$8.78		$12.74	$0.0503	$7.98	$12.13	0.907	2.000	116.7	393,000	117	1,706	493
Escalation	110%	110%		105%										

Notes:

[1] These rates include the escalation factor shown above to account for rate increases between now and the time the ECMs are implemented

[2] These factors are approximate for Cincy area. 1 metric ton = 1.102311 US or short ton

Present Cost			
Electric En.	Demand	Gas	Total
$18,642	$8,685	$20,690	$48,017

III. DISCUSSION

A. Utility Savings and Installation Costs

The *Annual Utility Savings* and *Installation Costs* shown in Table 2 are representative of the costs and savings that would result from implementation of the ECMs. The savings were computed using the present marginal utility rates, which were estimated from the historical load profile and the Duke Energy tariffs with the present riders. The marginal rates we used are shown in Table 3. These rates would also apply to the increased cost of air-conditioning the building.

The installation costs are intended to include materials, labor, engineering, project management, and a contingency for unknown conditions.

Due to the overview nature of this project, there was not sufficient time to generate highly accurate cost and savings estimates for the ECMs. The savings are based on experience or brief calculations that are made in the screening tool. The cost estimates are based on experience or a brief itemized list of tasks. For the cooling alternatives, the cost estimate is of a schematic-design level (component takeoffs based on the preliminary nature of the design). We included a 5% allowance for project conditions, a 10% allowance for contractor OH&P, a 10% contingency, and an estimated engineering fee.

B. Avoided Costs

Some of the ECMs in Table 2 may show favorable economics because a credit was taken for an *Avoided Cost*. For example, while the replacement of HID lighting fixtures may not yield sufficient energy savings to recommend outright replacement, the fixtures may soon reach the end of their life expectancy (as evidenced by failing ballasts, poor light output, corrosion, etc.). A complete lighting upgrade using T5 fluorescent lamps, combined with occupancy sensors and a time-of-day switching program, would allow the general lighting level to be controlled as appropriate for the space usage. For these types of projects, the *Total Installation Cost* shown is the incremental cost over-and-above the *Avoided Cost* to just replace in kind.

C. ECMs With No Calculations, Other Issues

Some opportunities shown in Table 2 were judged to be within the capabilities of school maintenance personnel or judged to be too small (in energy savings) to warrant further analysis. For these ECMs, project costs and savings were not estimated, but the ideas were left in the table as recommended projects.

Some of the projects are not recommended at this time, but may prove valuable with further analysis that is beyond the scope of this project and are so noted in the *Comments* column of Table 2.

D. Internal Rate-of-Return

For ECMs where costs and savings were estimated and for the sum of all of the recommended ECMs, an internal rate-of-return was calculated to show the life-cycle economics. Life-cycle costing takes into account the timing of cash flows for energy, maintenance, and other financial parameters over the life of the system. For this project, the following variables were used:

20 year project life
0% marginal tax rate
3% annual increase in utility rates
3% annual increase in maintenance costs

E. Opportunities Not Investigated

The following ECMs were not investigated due to the types of systems/processes in this facility or the experience of the team in analyzing other similar facilities. The economics and practicality may change as utility rates increase, technology advances, or equipment needs to be replaced.

- cogeneration systems to generate power and thermal energy on site
- absorption cooling
- photovoltaic panels
- wind generators
- additional wall, roof insulation
- glazing upgrades
- direct-contact wet economizers on boilers
- geothermal heating/cooling systems
- external window shading devices

F. Air-Conditioning Loads and Assumptions

The issues and assumptions we made in order to explore alternative systems include:

- The maximum building population is 455 students plus staff
- The maximum classroom population is 20 students plus staff
- The corridors, bathrooms, locker rooms are not as important to condition (rely on surrounding spaces to dehumidify and provide some level of temperature relief but do not provide cooling units for these spaces)
- The computer lab, offices, gym are all on their own cooling systems which are to remain; capacity could be provided in central systems to accommodate the computer lab and offices in the future but there is not a great value in doing so
- The library cooling would be part of the new system since its equipment is 20 years old and nearing the end of its useful life

- The system is assumed to operate from about 7am to 4pm weekdays; this timing is important for the thermal storage alternative discussed below; if the hours of use are greater, a larger chiller would be needed with thermal storage
- Current ventilation code requirements must be met, either through relying on operable windows or through a mechanical ventilation system; mechanical ventilation is preferred since the staff is unlikely to open windows when the weather is hot and humid and when external noise would disrupt the classroom environment; a mechanical ventilation system can also be used in the heating season to improve classroom conditions without opening windows; mechanical ventilation also provides filtered air rather than allowing dirt to be blown in through the windows; the existing operable window area does meet the code requirement (>4% of the floor area)
- The main electrical service has marginal capacity and will have to be upgraded from the present 800 amp capacity (the present peak load is about 350 amps); the service is 208 volt, three-phase which results in larger conductor sizes to large equipment than when fed at the more common 480 volts
- The existing heating system is not easily adaptable to a cooling system due to the small pipe diameters, lack of pipe insulation (which would cause condensation), lack of mechanical ventilation in many rooms, lack of any air-based terminal units (most of the classrooms have just finned tube convectors); we assumed that the existing heating system would for the most part remain intact and the new cooling system would be separate; exceptions may be the library, cafeteria, and additional classrooms which already have fan-coil type terminal units that may be adaptable to cooling

Based on the above, and assuming the east glass window film is added, we estimate that approximately 120 tons of capacity will be required in the new cooling system. Mechanical ventilation will add about 35 tons. With diversity in occupancy, the peak load for the new cooling system is likely about 150 tons.

G. Air-Conditioning Alternatives

Several candidate systems were identified that could meet the project requirements. They are listed in the following table. A weighted matrix was developed to compare each alternative without preparing cost and savings estimates for every case. The higher the score, the better that alternative is (10 points in *First Cost* is the lowest cost, 10 points in *Maintenance* is the least maintenance). The alternative with the highest total score is the best.

	First Cost	Op Cost	Noise	Comfort + Ventil	Maint	
Weighting factor	7	5	6	5	5	Total
1. PTAC units with minimum OA	10	6	4	6	5	179
2. split systems with minimum OA (similar to PTAC but with remote condensers)	9	6	8	6	5	196
2a DOAS ventilation system with split systems	6	8	8	9	5	200
3. 2 pipe fan coil units with minimum OA, central air-cooled chiller	6	6	8	5	7	180
4. DOAS ventilation system with water-source heat pumps, dry cooler to reject the heat from the loop	7	7	7	9	6	201
5. DOAS ventilation system with 2-pipe fan coils, central air-cooled chiller	5	8	8	9	7	203
6. packaged rooftop, cooling-only VAV units	4	6	8	8	8	186
7. DOAS ventilation system with radiant cooling panels or chilled beams, central air-cooled chiller	3	10	10	10	8	221
8. packaged rooftop, cooling-only VAV chilled water units, central air-cooled chiller	3	6	8	8	6	169

PTAC = packaged terminal air conditioning (motel type unit)
OA = outdoor air
DOAS = dedicated outdoor air system for providing ventilation air
VAV = variable-air volume system

The table shows that alternative #7 DOAS / radiant panel alternative scored the highest and alternatives #2a, #4, and #5 are closely ranked for second. We recommend #2a or #5.

The table below has comments about each alternative.

System Alternative	Comments
1. PTAC units with minimum outdoor air	noisier than fan coil systems due to compressors in the space can only provide a minor amount of ventilation air, requires operable windows to meet the ventilation code operating cost can be slightly lower than central chiller if units with a high EER are used (higher-cost units); individual units can be scheduled off or on as needed poor moisture removal; supply air temperatures are typically in the mid- to high-50s which is barely adequate for low density office environments, not for classrooms; during part load periods when the cooling load is low, there is virtually no moisture removal since the compressor is not running continuously; moisture that condenses on the coil when the compressor is running is re-evaporated into the space when the compressor cycles off many individual refrigeration systems to maintain shorter equipment life than chiller-based systems equipment can be serviced by many local service companies
2. split system fan coil units with minimum outdoor air	similar to #1 but noisy compressors are located remotely
2a DOAS (dedicated outdoor air system) ventilation system with split system fan coil units	good mechanical ventilation system; the DOAS would be sized for about 6,500 CFM of 100% outdoor air to meet the ASHRAE 62.1 ventilation code; it would contain a filter, a gas-fired modulating heater, a split-system cooling coil, wrap-around heat pipe (to deliver close to neutral air temperature to the rooms), and a variable-speed fan; the unit would be located on the roof with ducts penetrating the roof deck for each group of stacked classrooms and dropping down to the lower floors; air would be distributed to each classroom and the corridors with a high aspirating diffuser to promote good mixing; CO2 sensors would reduce the air flow when rooms are sparsely occupied good moisture removal many individual refrigeration systems to maintain shorter equipment life than chiller-based systems equipment can be serviced by many local service companies

3. 2-pipe fan coil units with minimum outdoor air, central air-cooled chiller	similar to #2 but only one refrigeration system to maintain slightly lower efficiency than high efficiency PTAC or split systems requires operable windows poor humidity control during part load conditions even if the fan coil units have face-and-bypass damper control instead of chilled water flow control must operate a certain minimum number of spaces at the same time in order to put enough load on the chiller to keep it from cycling chiller service must be done by qualified technicians
4. DOAS ventilation system with water-source heat pumps, dry cooler to reject the heat from the loop	heat pumps would be noisier than fan coils due to compressors in the space; noise varies as compressors cycle on and off many individual refrigeration systems to maintain shorter equipment life than chiller-based systems
5. DOAS ventilation system with 2-pipe fan coils, central air-cooled chiller	good mechanical ventilation system; the DOAS would be identical to #4 except cooling would be from the chiller quiet operation in the classrooms only one refrigeration system to maintain outdoor chiller system piping would have to be drained in the winter or glycol used
6. packaged rooftop, cooling-only VAV units	too expensive and difficult structurally to route large ductwork to every room due to the existing building configuration
7. DOAS ventilation system with radiant cooling panels or chilled beams, central air-cooled chiller	best system from energy efficiency, noise (no fans or compressors in the spaces), maintenance, and operating cost somewhat risky operation due to potential for condensation on chilled beams or panels if the DOAS provides inadequate moisture removal; requires higher air flow from the DOAS to insure adequate moisture removal from the spaces most expensive alternative
8. packaged rooftop, cooling-only VAV chilled water units, central air-cooled chiller	too expensive and difficult structurally to route large ductwork to every room due to the existing building configuration

None of the alternatives (except the VAV units) have a "free cooling" mode to use outdoor air for cooling when conditions are favorable. However, the DOAS does continue to bring in the ventilation air flow whenever it is running. Also, windows can still be opened when conditions are favorable.

None of the DOAS alternatives incorporate energy recovery, as is common in most DOAS configurations. We have assumed that all of the air provided by the DOAS will be exhausted via the bathrooms, locker rooms, and kitchen. The cost to add return air ductwork and energy recovery heat exchanger is not justified from the savings.

Other improvements could be made to the recommended system. Our strategy was to first reduce the cooling load as much as possible, then apply the best possible system to meet that load.

System Improvements	Comments
room CO2 sensors	a sensor could be installed in each room to reduce peak ventilation requirements based on occupancy; when students are in other parts of the building, the mechanical ventilation delivered to a room would be reduced; this would reduce the peak load and operating costs
window film	reflective film could be added to the inside surface of the east-facing glass to reduce the solar heat gain, thereby reducing the cooling system first cost and operating cost; the cost of east-facing window film is about the same as the savings in cooling equipment first cost; there is also a Duke Energy incentive program that pays up to $2/SF, which is about 40-50% of the installed cost; this is an excellent alternative the west-facing glass is less of an issue since school tends to be over by the time there is significant heat gain; with the incentive, it may be worth installing on the west glass as well the film should be tested on a small area to be sure that the appearance from both inside and outside is acceptable; the window supplier should verify that film will not cause problems with the double-pane assembly

full thermal storage system	thermal storage can be added to any of the central chiller alternatives allows a smaller chiller to be installed (120 tons instead of 150 tons); the chiller would only run during the off-peak demand periods (8pm to 11am weekdays); the reduction in chiller capacity is not enough to avoid the electrical service upgrade but the simple payback period is about 6 years with the Duke Energy rebates ($6,000 for storage, $5,000 for chiller) the system would consist of five modular ice tanks that could be buried in the ground or made visible (as an educational tool for the students?); during off-peak periods, cold glycol would be circulated through the tank coils, freezing water in the tanks; during on-peak periods, the chiller would be shut off and the ice melted to cool the building
partial thermal storage system	allows a smaller chiller to be installed than full storage (95 tons instead of 120 tons) and one less tank; the chiller would run at half load during the on-peak period; the reduction in chiller capacity is not enough to avoid the electrical service upgrade but the simple payback period is about 7 years with the Duke Energy rebates ($2,000 for storage, $4,000 for chiller)
main electrical service upgrade	the upgrade can be done by pulling a third feeder from the utility transformer in an existing conduit and upgrading the distribution switchgear; Duke Energy would likely need to upgrade their transformer on the pole (hopefully, at their cost); the existing loads would be backfed from the new service; the feeder to the new chiller would need to be sized for 208 volts alternately, the existing service could be changed to 480 volts by Duke Energy (hopefully, at their cost); the existing feeds would not need to be upgraded but a transformer would be required inside the building to step down the voltage to the existing loads; the feeder to the new chiller would be sized at 480 volts; due to the smaller size of this feeder, the overall cost of this alternative is about $10,000 less than the 208 volt alternative; there would be a small transformer loss penalty but during the heating season, this would help heat the building

display board	as suggested for the thermal storage system, the installation of the air conditioning system could be used as an educational tool for the students; a display board could be connected to the digital control system which would show a real-time diagram of the thermal storage system and its present mode of operation, demand savings, and other interesting energy system information; this cost was not included in the estimates

H. Cost Estimating Assumptions

The first costs and annual operating costs were estimated for six alternatives. Some of the assumptions we made include the following:

- Present utility rates escalated 10% for electric, 5% for natural gas to account for increases between now and when the systems are installed
- Five months of peak demand operation, seven months of demand ratchet penalty
- 800 full-load operating hours for the cooling system, 1,400 hours of fan operation
- 1.2 kW/ton chiller efficiency, and 1.0 kW/ton split system efficiency
- 117 kW past building peak demand load
- The electrical service would be upgraded by converting to a 480 volt service and reusing the two existing feeders
- Duke Energy will not charge to change out their transformer
- The existing digital control system can be expanded to support the new systems without totally replacing it
- The building floor and roof slabs can support the weight of the new equipment and holes can be cut for ductwork and piping to pass vertically between floors without reinforcing the slabs
- The present method of roof access is acceptable; we did not budget for providing a more convenient roof hatch
- If a chiller is used, it would be located in the front or rear of the building, on-grade; if thermal storage tanks are used, they would be located next to the chiller on-grade or buried up to the lids
- Desired rate-of-return is 12%/year; this equates to about a 9-year desired simple payback period

Note that the present electrical demand rates are less than $8/kW. Other Duke Energy territories and other Midwest utilities typically charge $12-14/kW. Higher demand costs would improve the economics of thermal storage.

H. Results

The following table compares the alternatives for which we prepared cost estimates. The Net Present Value shows the life-cycle cost over a 20-year period. It does not include equipment replacement costs.

Alternative	Estimated First Cost	Estimated Annual Operating Cost	Simple Payback Period, Yrs	Net Present Value
#2, individual split systems, operable windows	$431,000	$21,000	--	$620,000
#2a, individual split systems, DOAS	$725,000	$27,000	--	$968,000
#3, 2-pipe fan coils, 120-ton air cooled chiller, operable windows	$575,000	$24,000	--	$791,000
#5, 2-pipe fan coils, 150-ton air cooled chiller, DOAS	$822,000	$33,000	--	$1,119,000
#5a, 2-pipe fan coils, 95-ton air cooled chiller, DOAS, partial ice storage	$897,000	$22,000	6.7 re: no storage	$1,095,000
#5b, 2-pipe fan coils, 120-ton air cooled chiller, DOAS, full ice storage	$917,000	$16,000	3.3 re: partial storage 5.5 re: no storage	$1,061,000

The above annual operating costs include the cost of operating the DOAS system in the heating season. This is estimated to be about $3,000/year. Part of this cost may already be incurred if windows are opened during the heating season for fresh air.

The results show that for the systems with a DOAS, alternate #2a has the best life-cycle economics. Alternate #5b is a close second, and would have longer equipment life.